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THE

MASTER-BUILDER'S PLAN.

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THE

MASTER-BUILDER'S PLAN

OR THE

PRINCIPLES OF ORGANIC ARCHITECTURE

AS INDICATED IN

THE TYPICAL FORMS OF ANIMALS.

BY

GEORGE OGILVIE, M.D.

LECTURER ON THE INSTITUTES OF MEDICINE, ETC., IN MARISCHAL COLLEGE AND UNIVERSITY, ABERDEEN.

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PREFACE.

THE following observations were originally written for the Philosophical Society of Aberdeen, at the request of the secretary, and were in part read at a recent meeting.

The Author's object was to bring forward, in a popular form, the views now generally held by philosophical naturalists in regard to a common plan of construction, traceable in each of the primary divisions of the animal kingdom.

He has been led to the idea of publishing them by his own experience of the want of a popular treatise on the subject. The organisation of the higher animals, it is true, has been

very fully discussed, both in this country and on the Continent, since the first promulgation of the doctrines of Oken. The various works of Professor Owen, in particular, have brought the highly systematised views of that zoologist very extensively under the notice of the cultivators of Natural Science; while his treatise on Osteology, in "Orr's Circle of the Sciences," has, by the low price and extensive circulation of that serial, placed a concise summary of them within the reach of all. It can scarcely be said, however, that even this article takes the place of a popular treatise, for the great aim of the distinguished author, here as elsewhere, being to trace the varied forms under which corresponding bones reappear in the different modifications of the vertebrate skeleton, he is necessarily led into many intricate anatomical details; and the subject of Osteology is but little attractive to the general reader under any treatment.

The organisation of the lower or invertebrated species has naturally attracted less attention on account of their comparative removal from common observation; and, till a very recent period, our acquaintance with their structural relations was far too limited to admit of any general conclusions. Of late, however, the study of most of these lower tribes has been so diligently and successfully prosecuted by various inquirers, that we are now in possession of many admirable dissertations on their several types or plans of construction. But the separate branches of the subject having been taken up independently by different naturalists, their remarks are dispersed through a variety of periodicals and other serials. In general, too, they are addressed to readers who have already a fair knowledge of the departments of zoology to which they refer.

As a part, indeed, of a much larger question, many points in the general construction of the primary groups of animals are brought under review in a recent work, "Typical Forms and Special Ends in Creation," by Drs. M'Cosh and Dickie. Here, in so far as it fell in with the general scope of the work, the latter author has, by a judicious combination of the scattered materials above referred to, presented us with a summary of the principal forms of organisation, expressed in language at once accurate and readily intelligible.

In so far, again, as these forms are illustrative of General Physiology, they have also engaged the attention of Dr. Carpenter in most of his writings. In particular, he has introduced the subject in the course of the opening chapter of his last treatise on "Comparative Physiology;" and in the larger work of the same indefatigable author on the "Principles of Physiology, General and Comparative," we

have a full and comprehensive survey of the principal forms of animal life. Though more regard is naturally paid in it to the functional than the morphological import of the organisation of the lower tissues, yet if this part of the book is reproduced, as we are led to expect, in a separate form, and with the corrections rendered necessary by later investigations, there is reason to hope it will go far to supply the deficiency which has been complained of in the literature of the science.

In the mean time, the present sketch of the leading plans of construction which prevail in the animal kingdom, is offered for the favourable consideration of the public, till some fuller work, and one by an abler hand, is called forth by the conviction which is every day becoming more general that a certain acquaintance with natural science is a necessary element of a truly liberal education. To originality, his work makes so little pretension,

that even were the trite judgment passed upon it that what is true is not new, and what is new is not true, the Author certainly would not feel this a very severe condemnation. His great object, indeed, is not to advance new truths, but rather to gain additional currency for such as have a fair claim to be already established, and, in particular, to convey an idea of the laws of organisation to those who, without making natural history a special object of study, may wish to have a right comprehension of its general scope.

Having such readers mainly in view, he has endeavoured to avoid, as much as possible, the use of technical language when he could avail himself of the modes of expression in more common use.

In so doing, he is prepared to find that he has proportionally exposed himself to the charge of deficiency in scientific precision; but this, in the case of the general reader, is

a matter of comparatively small importance; while if the outline here sketched induce any to prosecute the study farther, the fuller details given in the various special treatises, of which a list is affixed to the work, will afford abundant means of supplying its defects.

Marischal College,
Aug. 5, 1858.

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THE

MASTER-BUILDER'S PLAN.

CHAPTER I.

THE VARIOUS PLANS ON WHICH ANIMALS ARE FORMED.

ALL natural objects with which we are acquainted admit of a ready division into inorganic bodies, and those possessed of life and organisation; and the latter are with equal facility recognised as being either of a vegetable or an animal nature. There are, it is true, some ambiguous species, in regard to which there is a certain difficulty in determining on which side of the dividing line they should be placed; but as these cases are quite exceptional, and entirely confined to the lowest divisions, they do not throw any real impediment in the way of distinguishing plants from animals.

But it is to be observed, that this distinction is

based much more on the characteristic actions of the two kinds of beings than on their forms. Thus, in popular language, animals are distinguished from plants by their being possessed of the faculty of sensation and the power of locomotion; and although the physiologist, knowing that these endowments are not coextensive with animal life, may prefer to use other points of distinction, — as the differences in the food and respiration in the two kingdoms of organic nature, or the general absence of irritability, and the small proportion of nitrogen commonly present in the tissues of plants, — yet his characters, like the popular ones, mostly have reference to the actions proper to the two kinds of existence, rather than to differences in form.

We are, in fact, precluded from employing the latter as distinctive marks, by the impossibility of fixing on any definite form as characteristic of animals in general. The stomach is the only structural peculiarity which can with any feasibility be alleged as a *constant feature*, and this only with some qualification. For in some of the lowest forms of animals* there would appear to be no permanent cavity of this nature; only there is formed a sort of extemporaneous one for the reception of food; either by the

* Some of the infusory animalcules.

morsel being forcibly thrust into the soft substance of the body, or by the latter wrapping itself round the object which is to be subjected to its digestive powers.

But even looking on such cases as exceptions which prove the rule, still, as we cannot allege so much of any other organ, we are as far as ever from any general form common to all animals. We cannot, for instance, say in what direction the body should be extended, what sort of appendages it should have, or how they should be arranged; we can predicate nothing of its supporting framework, or of the conformation and disposition of its internal organs. Hence the impossibility, apparent on a moment's reflection, of making the rudest sketch, or even conceiving one, which shall stand for an animal in general, without the specialities of any particular class, — of delineating anything which, without representing exclusively a star-fish or a snail, a worm or an insect, a fish or a bird, a reptile or a quadruped, or any other *particular kind* of animal, shall yet indicate so much as is common to them all.

Not that it is intended to deny the possibility of assigning a common form, which shall be more or less applicable to *many* different animals. The expressions used have, indeed, quite an opposite mean-

ing; for in providing that the imaginary representation shall not be that in particular of an insect, a bird, a fish, &c., it is clearly implied that the numerous species comprehended under each of these names have so many characters in common, as to make it possible to give a delineation more or less applicable to them all. In fact, giving a common name to the group of itself implies so much.

Such community of structure is much more remarkable in some groups than in others, and it always becomes less obvious as we pass from the smaller to the larger sections. Still, it obtains to a certain extent in each primary division of the animal kingdom, or in such of them at least as have a clear title to be considered natural groups.

As it is the characteristic conformation of these groups, and the more special modifications marking the subordinate classes, which will be the subject of consideration in the following pages, a few remarks may here be premised with advantage in reference to classification.

The arrangement of Cuvier, by which animals were divided into the four primary groups of Vertebrata, Articulata, Mollusca, and Radiata, is still retained by most naturalists; though by general consent there are detached from the last of these certain species at

the bottom of the scale (such as sponges and infusory animalcules), to which the name of Protozoa (or Rudimentary Animals) has been applied, from their occupying a sort of debatable ground between the two kingdoms of organic nature.

In the group Radiata are comprehended two classes, — one termed by Mr. Huxley Cœlenterata, which contains the polyps and jelly-fishes; and another, long known by the name of Echinodermata, in which are placed the star-fishes and allied animals. Of Mollusca the most important classes are the Bivalve shellfish, like the oyster; those like the periwinkle, with a single shell, which is generally coiled into a spiral; and the more highly organised family of cuttle-fishes. The Articulate group, besides various worm-like animals, contains centipedes, insects, and those species which are more or less allied to crabs and spiders; whilst the highest group, Vertebrata, is divisible into the four classes of Fishes, Reptiles, Birds, and Mammalia, to which last naturalists refer the human species.

In the following remarks attention will be directed mainly, and in the first place, to the Articulate and Vertebrate groups, which appear to form a natural series distinguished by some remarkable peculiarities, wanting in the other two, especially by the presence

of a jointed framework or skeleton, for the support of the soft parts of the body. This is a character indicated by their names, Vertebrata and Articulata, meaning respectively *hinged* and *jointed* animals, and suggesting the same general idea of a series of parts, so connected as to turn on each other, in the manner of a hinge or joint. All these animals, in fact, have in so far the same general conformation, that their skeleton consists of a series of pieces placed one in front of the other, so as to form an elongated shaft, which, notwithstanding the rigid nature of the several parts, has a certain flexibility, owing to the numerous joints connecting these together. At the anterior end of this column is the head, in which, along with the principal organs of sense, is situated the mouth or anterior opening of the alimentary canal, closed by movable jaws. The animal is also furnished with locomotive organs or limbs, all having a downward direction, and jointed like the shaft of the skeleton, to which they are connected in pairs. The arrangement of these parts, and indeed the whole organisation of the animal, is highly symmetrical in its earliest condition, although in many cases, as the embryo assumes the characters of the adult, this is interfered with by the disproportionate development of certain organs of the body.

But Vertebrate and Articulate animals agree farther in some respects which do not seem to have any necessary dependence on this segmentation implied in their respective names. In both groups the central tract of the nervous system forms a cord along the axis of the animal, with its anterior extremity developed into an organ having a certain analogy to the human brain. In both the central organs for the circulation of the blood are a contractile vessel or heart, propelling the blood towards the head, and an arterial trunk returning the main current in the opposite direction.* In both the digestive system is represented by a canal running in the length of the interior of the body, and opening before and behind by appropriate orifices on the lower aspect of the animal.

On the other hand, although these several systems agree in many of their relations in the two groups, in some points they are as strikingly contrasted. Thus the skeleton, which is mostly confined in Vertebrata to the interior of the body, is wholly external in Articulated animals, so that the jointed character is at once apparent in them, while in the former it is

* It is only in some of the more typical Articulata that this median returning arterial vessel has been observed, as will be explained afterwards at greater length.

so obscured by the investing layer of soft parts, as almost to escape notice, till exposed by dissection. Again, the position in the body of the vascular, nervous, and alimentary systems, is completely reversed in the two groups, notwithstanding the close correspondence of many of their details.

As neither the points of agreement, nor those of difference, can be well appreciated without a correct idea of the general organisation of the animals compared, we must now proceed to take a short survey of the great anatomical systems of the body in each group, beginning with the Vertebrata.

CHAP. II.

THE VERTEBRATE TYPE.

BEFORE entering on details of organisation, a few preliminary remarks may be offered, which have a certain bearing on all the primary groups.

The position which may be regarded as normal, in the case of Vertebrata, is the horizontal, or that with one of the symmetrical surfaces of the body turned downwards; but this is not without exception. Thus the Pleuronectidæ, or flat fishes, rest on one side, generally the right. As the body is much compressed laterally, and the two sides are generally of different colours, while, by a peculiar twist of the bones of the face, both eyes are brought round to the upper surface, the right and left sides in these fishes have come, by a natural misnomer—attesting the constancy of the normal position—to go under the names of belly and back. Of more practical importance is the erect position, not indeed as it appertains to a particular region only—the neck in birds, for

instance—nor even as a posture assumed but occasionally and imperfectly by a few apes, rodents, and marsupials, but as the natural attitude of our own species. For in consequence of this diversity in the gait of men and animals, such terms as upper and lower, fore and hind, have different meanings in human and comparative anatomy. In the following remarks, then, it may be proper to mention that the animal will be supposed in the horizontal position natural to it. Farther—to avoid circumlocution—the term *aspect* will be used in reference to the upper and lower surfaces of the body, that of *side* being restricted to those which are directed to the right and left; the back, accordingly, will be described as the dorsal or upper, and the belly as the ventral or lower aspect.

The same course will be observed in treating of the Articulata, in which, indeed, the horizontal position is even more constant than in the higher group, the Barnacle tribe probably forming the most prominent exception, though there seems to be also a partial deviation from the horizontal in the direction of the axis of the head in insects.* In Mollusca, again, there is less constancy in the position of the body,

* Goodsir, in Ed. New Phil. Jour. Jan. 1857.

though in the more typical species it coincides with that characteristic of the Articulata. In the lower groups an axis is either not discernible at all, or it has an erect or inverted, rather than a horizontal direction.

The organs of the animal body naturally resolve themselves into a few great anatomical systems. Of these the most conspicuous is the skeleton, or hard supporting framework, forming, along with the muscles by which its various parts are moved, one or more general cavities for the accommodation of the internal organs or viscera. Of the latter, the most important are the nervous centres, with the filaments which put them in communication with the rest of the body—the vascular mechanism for the circulation and aëration of the blood—and the alimentary canal, with the associated organs, for the performance of the function of digestion. Of these systems the last—as has been intimated—is the most constant in the animal series, while the vascular is the first to disappear as a distinct element, the movement of the fluid contained in the general cavity of the body taking the place of a true circulation in the lower species.

The skeleton in Vertebrata, though forming, as in other animals, the shell of the body, is mainly in-

ternal, in the sense of being covered over by the flesh or muscular tissue; while in Articulata — as has been mentioned — it is external, the muscles lying on its inner surface, and acting upon plates or bars which project from its interior. In the lower groups the skeleton continues in general to hold this external position, though it is a less constant element. The external skeleton of the invertebrated animals, however, is not entirely unrepresented in the higher groups, for Vertebrata have always their outer envelope, or parts of it, more or less hardened as a defence to the tissues which it enfolds. Generally, indeed, the induration is less in degree than in the internal skeleton, and due to a horny instead of a calcareous deposit; still, as there are some notable exceptions to this, and as in all cases a tegumentary investment exists, distinct from the internal skeleton, it is proper to include both in an enumeration of the great systems making up the vertebrate organisation.

These we shall now therefore proceed to consider in the following order: the osseous or internal skeleton, the tegumentary or external skeleton, the nervous, the vascular or circulatory, and the alimentary.

The osseous or bony system is here identified with the internal skeleton, because the framework which gives shape and support to the animal is, in the vast

majority of cases, mainly of a bony nature; although it is always eked out with cartilage or gristle, and in a few species is entirely formed of this material.

The part of the skeleton which first demands our attention is the spine or backbone, to which the name of vertebral column has been given, from the way in which its numerous component bones — or vertebræ, as they are termed — hinge or turn upon each other. It is this vertebral column which has given its name to the great division of animals in which it occurs: and rightly so, as being the most important element of the skeleton; the first to appear in the development of the embryo, the most constantly present in all species, and, moreover, the central pillar to which are attached, directly or indirectly, all the other bones of the body.

But the philosophical naturalist embraces much more than this central pillar in his idea of the vertebral column, for he views the whole skeleton as nothing else than a pile of vertebræ; all its bones being considered as only more or less outlying portions of the several joints of the spine. This view is founded on the conception of a vertebra including three primary elements, — a central portion or body, and two arches or wings, which in the horizontal position of the animal are situated on its upper and

lower aspects.* When these bones are in their natural connection, the bodies form by their superposition the massive column of the spine, while the superior arches jointly form a latticed canal, termed *neural*†, or nervous, from its lodging the great nervous cord; and the inferior arches form another, called *hæmal*‡, from its enclosing the heart and other blood organs along with the alimentary canal. This hæmal canal is much more irregular than the neural; it is in some places very defective, so far as the bony skeleton is concerned; but when it has such bony walls, it is in general much larger than the other, from the greater bulk of the organs it has to enclose. Of this we have illustrations in the chest and pelvis, where the whole circuit of the ribs and breastbone in the one, and of the pelvic bones in the other, are considered as entering into the hæmal arches of the corresponding vertebræ. The regions where its bony walls are defective are the neck, the abdomen or belly, and the tail, where, in most animals, it is completed only by the soft fleshy tissues; though comparative anatomy makes us acquainted with a few species in which, even in these regions, there is a

* For various modifications of vertebræ, see Pl. I.

† Gr. *Neuron*, a nerve. ‡ *Hæma*, blood.

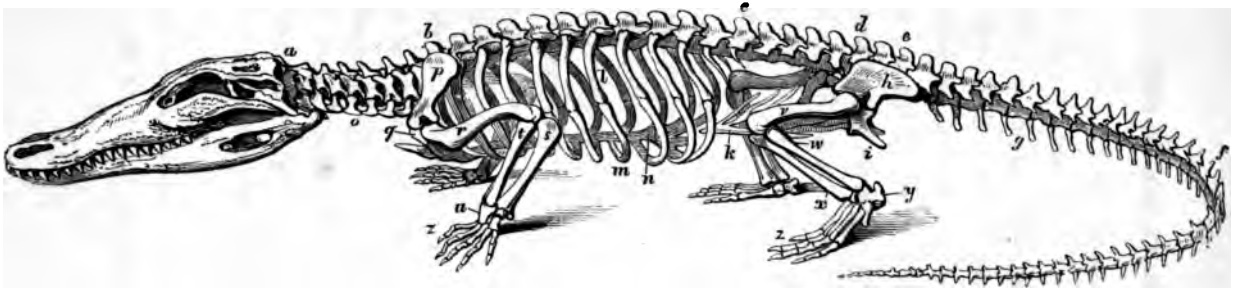

Fig. 1. SKELETON OF THE CROCODILE.

a b, cervical vertebræ, bearing rudimentary ribs *o*; *b c*, thoracic vertebræ; *l m*, ribs, and *n*, sternum of the same region; *c d*, lumbar or abdominal vertebræ; *k*, abdominal sternum, bearing ribs which do not reach to the spinal column; *d e*, sacral vertebræ; *f*, caudal vertebræ, bearing hæmal arches on their inferior aspect, as well as neural arches above; *p*, *q*, *r*, *t*, *s*, *u*, *z*, bones of the shoulder and fore-limbs; *h*, *i*, *v*, *w*, *x*, *y*, *z*, bones of the pelvis and hind limbs.

greater or less development of inferior bony arches. Thus the skeleton of man (*fig.* 19.), of the lion (*fig.* 14.), and of most land animals, presents a great vacuity in the space between the chest and pelvis, or what is termed the abdominal region, because the inferior wall of the body is there formed entirely of soft and perishable tissues; but in the crocodile it is different, as is shown in the figure in the foregoing page. In this animal the sternum or breastbone is prolonged backwards to meet the pelvis, and sends out on each side rib-like bones, which tend towards the spine. Of these bones, the only representatives in man are the tendinous cord, which connects the breastbone with the pelvis, and those transverse lines on each side by which artists seek to indicate the muscular development of this part of the body. As these abdominal ribs do not quite reach the backbone, the hæmal canal is not absolutely complete in the crocodile's skeleton, but what is wanting is supplied, as it were, by that of the serpent (*fig.* 2.), in which, though there is no breastbone, ribs as complete as those of the chest are continued from high in the neck on to the termination of the abdomen, or even beyond this into the tail.

The tail, however, in the greater number of animals has its vertebræ more defective than any other region

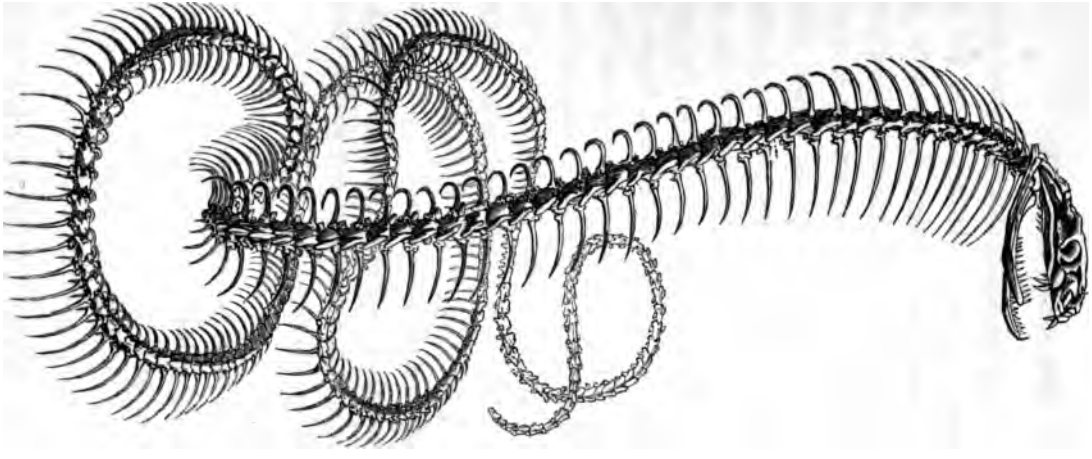

Fig. 2. SKELETON OF THE COBRA (*from Orr's Circle of the Sciences*).

Showing the absence of a sternum, and the ribs continued nearly the whole length of the spine; showing also the deficiency of limbs.

of the body. An attenuation of the spinal column, indeed, we should expect in the tail, for by this term is properly implied that portion of the body lying behind the termination of the voluminous alimentary canal, in which there is only the continuation of the main artery to occupy the hæmal canal. But in general it is more than attenuated; it is positively deficient in some of the characteristic elements of its vertebræ. This is the case not only in the human species, where the caudal appendage is so rudimentary that there is no external projection, its two or three minute bones being buried among the soft parts: it is true also of the greater number of the lower animals. Even when the tail is long and bulky, as in the ox, lion (*fig.* 14), and elephant, its bony core generally consists only of a series of small solid bones, representing the bodies of the vertebræ, while their neural and hæmal arches are totally unrepresented. Yet we have several exceptional cases, in which these arches are continued far on towards the tip of the tail; only the canals, especially the inferior one, are much reduced in size, in correspondence with the small bulk of the nerves and blood-vessels of the region. The crocodile among reptiles, the kangaroo and the whale tribe among mammalia, and

the greater number of fishes, afford illustrations of this arrangement.* (Pl. I.)

The neck is another region of the body in which the bony walls of the hæmal canal are very deficient. At the same time it is one in which comparative anatomy furnishes us with fewer materials to fill up the blank presented in the case of the higher animals. It must, however, be borne in mind, that in one large class of vertebrated animals there is no neck, the head in fishes being set directly on the trunk. A true neck is peculiar to the higher Vertebrata, being let in, as it were, between the head and chest, for the purpose apparently of giving the former free motion upon the body. It is probably on this account that the hæmal arches of the interpolated vertebra are so defective, there being no bone in this region corresponding to the sternum, nor any distinct ribs. Yet not only do serpents, as already mentioned, furnish well-marked exceptions to the general absence

* Professor Owen, however, does not admit any *exact* correspondence between the fish and the air-breathing Vertebrate in the bones which compose the hæmal arch in the tail, as in the latter it is made up of bones holding the same place that the sternum and cartilages of the ribs do in the chest; while in the fish, in whose skeleton no such bones occur, it is formed by the coalescence of others equivalent to ribs, or more commonly of those lateral appendages to which anatomists give the name of the transverse processes of the vertebræ.

of cervical ribs, but even in the higher animals it has not escaped notice that there are indications of rudimentary structures of the same nature. For we find in the vertebræ of the neck, that each lateral wing or transverse process is perforated at its base, and that the part below the hole stands in much the same relation to the rest, that the head and neck of a chest-rib do to the corresponding process of the vertebra with which it is connected. In fact, as an occasional variation in some Mammalia, and as the normal arrangement in a species of sloth, this portion of the last cervical vertebra is actually prolonged into a short rib. In the crocodile (*fig.* 1), too, there is an evident suture or line of junction between that part of the process which corresponds to the rib and he rest of the vertebra.*

The uniform development of the bony walls of the neural canal throughout its whole extent, or at all events till we come to the tail, has reference, no doubt, to its lodging the great central tract of the nervous system, the protection of which seems to be the main office of the internal skeleton, as that of the body at large is of the external or skin skeleton. In all regions of the body, indeed, the neural canal is

* Coote's Homologies of the Human Skeleton, p. 13.

closely moulded upon the nervous mass contained within it; and hence it happens that while in the trunk generally, where it encloses only the slender spinal cord, it is of far smaller size than the hæmal canal, these relations are reversed—at least in the higher animals—when we come to the head, where the neural arches are expanded into the skull-cap, so as to provide a capacious cavity for the reception of the brain.

Mr. Owen considers the bones of the skull to represent the parts of four vertebræ, whose hæmal arches are represented in the fish by the upper jaw, the lower jaw, the bones supporting the gill-fringes, and those of the shoulder. The space contained between these arches and the bony floor of the brain-case, is occupied by the mouth and gullet, and by the great blood-organs of the region.

In the higher animals the relations of the jaws continue unchanged, but the shoulder-bones—which in the fish are uniformly attached to the hind segment of the skull—are separated from it by the introduction of the neck. Those again supporting the gills are represented by the hyoid bone; but this, though also displaced and comparatively undeveloped, still retains its connection with the preceding segment of the skull, and in a manner embraces the

windpipe and gullet, along with the great arteries of the neck, by means of two tendinous cords—the stylo-hyoid ligaments of anatomists—which in some animals are actually converted into slender bones.

In the foregoing summary it will be found that all the bones of the skeleton—with the exception of those of the limbs—have been included as elements of the several vertebræ.* But even the limb-bones Professor Owen thinks accessories of vertebral segments. He considers them as offsets from the hæmal arch, greatly developed, indeed, to fulfil certain special ends, but not differing in nature from some small accessory bones which project from the ribs of birds; and he applies to both alike the name of diverging appendages. His views on this subject receive support from the relation in which the rudimentary limbs of certain fishes and aquatic reptiles stand to the hæmal arches of the vertebræ in these animals, as will be seen on a comparison of the vertebræ of the pelvic series in Plate I.

As a recapitulation of the foregoing remarks, a summary is here subjoined of the views of this

* There ought to be excepted also, according to Mr. Owen, those bones of the skull which specially protect the organs of sense, as these are not regarded by him as proper parts of the internal skeleton.

PROFESSOR OWEN'S VIEW OF THE HOMOLOGICAL RELATIONS OF THE VERTEBRATE SKELETON.

To face p. 23.

Vertebræ of		Hæmal Arches.	Centres.	Neural Arches.	Hæmal Diverging Appendages.
			Ossicles of Nose.		
Skull	1	Palate and Upper Jaw Bones	Vomer	Ethmoid and Nasal Bones	Pterygoid Process, Malar, and Upper Part of Temporal Bone.
	2	Part of Temporal and Lower Jaw Bone	Upper Part of Sphenoid Bone	L. Wing Sphenoid, and Frontal Bone	*Gill Cover of Fish.*
	3	Styloid Process and Hyoid Bone	Lower Part of Sphenoid Bone	G. Wing Sphenoid, and Parietal Bones	Gr. Cornua of Hyoid Bone—*Lingual Bones of Birds, Branchial Rays of Fishes.*
	4	Scapula and Coracoid Process	Basilar Process of Occipital B.	Occipital Bones	Upper extremity.
Neck	1	Clavicle	Bodies of Vertebræ	Spinous Processes of Vertebræ.	
	2-7	Transverse Processes—*Cervical Ribs of Crocodile*			
True Thorax	1-6	Transverse Processes—Ribs, Costal Cart. and Sternum	Bodies	Spinous Processes	*Costal Appendages of Birds and Fishes.*
	7	The same, with Ensiform Cart.			
False Thorax	1-5	Transverse Processes, False Ribs, Linea Alba. *Abdominal Sternum, and Abdom. Ribs of Crocodile.*	Bodies	Spinous Processes	*Costal Appendages of Birds and Fishes.*
Loins	1-5	Transverse Processes, Tendin. Intersec. of Recti, Linea Alba *Abdom. Sternum, and Sterno-Abdom. Ribs of Crocodile. Marsupial Bones of Kangaroo.*	Bodies	Spinous Processes	*Costal and Epipleural Appendages of Fishes.*
Sacrum	1-5	Lateral Process of Sacrum, Ossa Ilii, Ischii, and Pubis, Ischiat. Ligament	Body of Sacrum	Post. Wall of Sacral Canal	Lower Extremity.
Tail	1-*x*	*Chevron Bones of Tail of Crocodile, Whale, and Kangaroo Ventral Spines of Fish*	4 or 5 Coccygeal Ossicles. *Tail Bones of Animals*	*Caudal Spines of Fish, Crocodile, and Whale.*	

Number of Vertebral Segments in Man, 38.

zoologist, which receive the very general assent of naturalists. Mr. Owen regards the skeleton as formed of a chain of vertebræ, each consisting of a solid central piece or body, and two arches, an upper and a lower, the latter occasionally furnished with certain diverging appendages.

These vertebræ make up by the juxtaposition of their bodies the solid shaft of the spinal column, above which their upper arches form a canal for the nervous cord, while below the inferior or hæmal arches enclose one for the reception of the organs of digestion and circulation. The vertebræ, however, are not all alike, but differ considerably as to details in different regions of the body. In particular the four anterior are a good deal altered from their typical form, and more or less fused together to form the compact bony shell we term the skull, in which the neural canal or cavity for the reception of the brain is much larger — in the higher animals — than the cavities of the mouth and nose which here represent the hæmal canal. Throughout the whole middle region of the spine or trunk of the body, the neural canal is of uniformly small dimensions, and its arches, though fully ossified, are not run together except at its hinder part, where they go to form the bone called the sacrum, which transmits the weight of the

spine to the hinder limbs. The bony walls of the hæmal canal are more or less defective in two regions — the neck and the loins — but where they are fully developed, as in the chest and pelvis, they enclose a much larger cavity than the corresponding neural arches. In the case of the vertebræ at each extremity of the trunk, a pair of diverging appendages are amplified into the limbs of the animal. Lastly, in the caudal region or tail, the neural and hæmal arches are about equally developed, or more frequently are both wanting, and the spine reduced to a chain of small bones representing the bodies of the vertebræ.

These points in the disposition of the osseous system or internal skeleton of Vertebrata it was necessary to notice with some detail, as affecting the framework which mainly determines the conformation of the group: of the other systems a more cursory survey will suffice for our present purpose.

The tegumentary system is in general little developed in Vertebrata, appearing only in the form of hairs, feathers, or scales, which are for the most part of a horny nature, though some of them are occasionally converted into bone. When this occurs to any great extent, we have formed a real external skeleton, exhibiting indications of divisions into segments, much in the same way as the vertebral column

within. Of this we have examples in the armadillo, the tortoise (*fig.* 12), the crocodile, and a few fishes,

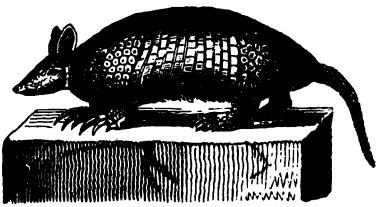

Fig. 3. ARMADILLO (*Dasypus*).

Showing the annulated character of the external skeleton.

as the *Hippocampus*. No such segmentation is to be seen when the integument remains soft, as it generally does; even that of the internal skeleton ceasing to be apparent on the exterior from the investing layers of skin and muscle. In most fishes,

Fig. 4. THE FISH CALLED THE SEA-HORSE (*Hippocampus*).

however, the muscular tissue itself partakes of the segmentation of the spine, as shown in *fig.* 5; hence the flaky appearance of the flesh when boiled.

Of the three great internal systems—nervous, vas-

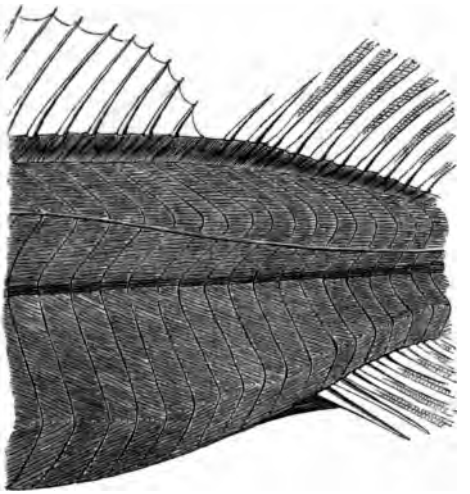

Fig. 5. MUSCLES OF THE PERCH.

General view of the disposition of the muscles in the body of the fish (after Cuvier), showing the annular arrangement of the tendinous intersections.

cular, and digestive — the general arrangement has already been indicated. The principal tract of the nervous system is situated on the dorsal aspect of the animal, extending the whole length of the spine, whose neural canal it occupies under the various forms of the brain, the spinal cord, and the terminal leash of nerves.

On the lower or ventral aspect of the body, again, we have the central organ of the system in which the

blood circulates. In the embryonic condition of the animal this organ commences posteriorly by a venous trunk communicating with a heart of two chambers, from the foremost of which a large vessel proceeds, termed the arterial bulb. Through these four successive cavities on the ventral aspect of the body, the blood moves from behind forwards, the bulk of it being conveyed through the right and left ascending branches of the arterial bulb into the great dorsal vessel or aorta, which is formed by their junction. This vessel, which is situated immediately under the spinal column, carries the blood back again to the posterior parts of the body. The vascular loop which thus connects the heart and aorta, remains as a permanent structure in the lower classes, but in the higher Vertebrata one side of it is subsequently obliterated, so that the communication is effected by a single vessel, well known to anatomists as the arch of the aorta.

Lastly, the alimentary canal, which is the most important portion of the digestive system, occupies, for the greater part of its extent, nearly the central line or anatomical axis of the body, lying in a position intermediate between the heart on the ventral aspect, and the aorta, spine, and nervous cord, on the dorsal. At its two extremities it turns downwards from its

central position to gain the exterior of the body on its hæmal or lower aspect. Anteriorly its line of communication with the mouth passes through the vascular loop already described as connecting the heart with the aorta. This arrangement is universal in fishes, and it is seen also in the embryonic condition of the higher Vertebrata; and even in the adult, when one side of the loop has disappeared, the other, under the name of the arch of the aorta, continues to describe a curve round the gullet.

The various systems whose arrangement has now been sketched, may be represented in position, as in Pl. II. *fig.* 1, by an ideal section of a vertebrated animal from above downwards along the middle line or axis of the body. In the head at the anterior end of the animal, we find the mouth leading into the alimentary canal, which lies in the central line of the trunk, and terminates posteriorly by another opening at the commencement of the tail. Both orifices are placed on the under surface of the body, being that to which the limbs are attached.

The heart, or series of contractile cavities propelling the blood forwards, is also situated on the lower aspect, which has on this account been termed hæmal. The ventral vessel or heart, which is situated below the alimentary canal, communicates in front with the

great returning vessel or aorta, lying above it, by a vascular loop, the limbs of which embrace the anterior portion of this canal.

On the dorsal or upper aspect of the body, again, we have the spinal column running the whole length of the animal, so as to project beyond the trunk, both in front, where it is developed into the head, and behind, where it forms the attenuated tail. Immediately below the spine is the arterial trunk just referred to, which carries the blood backwards, while in the canal on its upper surface lies the nervous tract, from which this aspect of the body receives the name of neural.

These relations of parts as superior and inferior can of course be shown in any particular region by a section transverse to the axis, as in Pl. III. *figs.* 1 and 2, but a longitudinal one, such as supposed, is required to exhibit them in all the regions at once.

CHAP. III.

MODIFICATIONS OF THE COMMON TYPE IN THE SEVERAL CLASSES OF VERTEBRATA.

THE arrangement now indicated may be considered as common to all vertebrated animals, subject to certain modifications in the several classes, in harmony with the peculiarities of each.

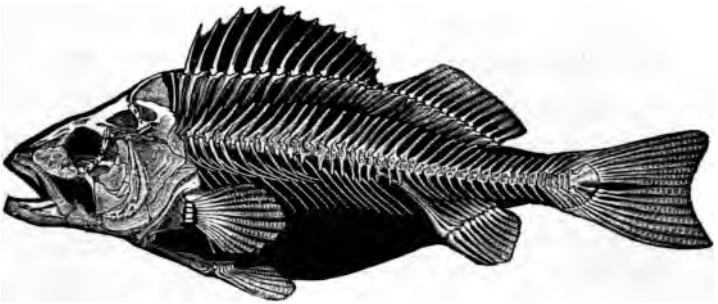

Fig. 6. SKELETON OF THE PERCH.

Showing the absence of a neck, the great development of the median fins, and the aberrant position of the ventral fins, which in this species are attached, along with the pectoral or fore-fins, to the hæmal arch of the last vertebra of the head.

Thus in fishes the inferior or hæmal arch of the skeleton is incomplete in the middle region of the

body from the absence of its key-stone, the sternum. We farther remark that there is neither neck nor pelvis, the head being set at once on the trunk, while the latter behind merges gradually into the tail, whose commencement is determined mainly by the termination of the alimentary canal; for in the majority of fishes there is no marked attenuation in this region of the body, and the position of the fins, answering to the hind-limbs of other animals, is very

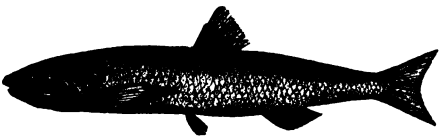

Fig. 7. ANCHOVY.

Showing the ventral fins, in a position corresponding to the hind-limbs of other animals.

inconstant. This variability indeed—which may be owing to their not being connected to the spine by any bony girdle or pelvis—is so great, that in some species they are situated in front of the other pair. The latter, corresponding to the fore-limbs of other vertebrates, are, on the other hand, remarkably constant in their point of attachment, being uniformly connected with the occipital or hind-segment of the skull; that is, with the last of the four modified vertebræ, making up this region of the skeleton.

But the feature which, in the majority of the class, is perhaps the most striking at first view, is the development of large fins along the middle line, by the extension of the external skeleton or indurated tegumentary system. Of these median fins there are generally two on the back, another on the belly, just at the commencement of the tail, and a large fan-shaped one at the extremity of that organ. In flat fishes (such as the turbot and flounder) all these fins

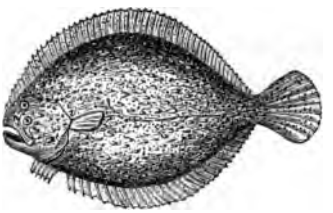

Fig. 8. PLAICE.

Showing the median fins united into a continuous fringe along the hæmal and neural margins.

are run into one, so as to form a sort of fringe or border, extending quite round both the upper and under margins of the body. In many fossil, and a few existing species of fish, the ossification of the integument is not confined to the median fins, the whole surface of the body being invested with bony plates of various forms and degrees of development. Of this we have examples in the sturgeon, bony pike,

trunk-fish, &c. But in the majority of those now inhabiting our seas the integument in general is little developed, and is protected only by small scales of a horny consistence.

Of the internal organs, the nervous tract is remarkable for the low development of the brain,

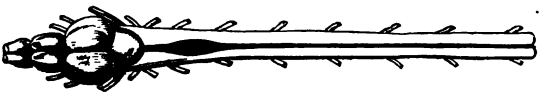

Fig. 9. ANTERIOR PART OF THE NERVOUS AXIS OF A FISH (*Cod*).

Showing the brain reduced to a double chain of ganglia at the fore-end of the spinal cord. The ganglia of the anterior pair are the centres of the nerves of smell; those of the second represent the brain proper in the higher animals, or rather, certain nervous masses at its base; those of the third pair are the centres of the nerves of vision; the hindmost ganglion is single, and represents the cerebellum or lesser brain.

which is reduced to a mere chain of ganglia or small rounded masses, forming an extension forwards of the spinal cord. The alimentary canal, too, is very simple, the uniformity of its course, from the anterior to the posterior orifice, being varied only by a few flexuosities, and by the pouch of the stomach, which lies almost immediately behind the mouth.

It is the blood-system which presents the most marked peculiarities. Like the others, it is less developed than in the higher animals, but this does not so much appear in its absolute simplicity, as in its

closer adherence through life to that form which prevails in all vertebrate animals during the period of embryonic existence. Not but that even in fishes a certain amount of change takes place. The ventral vessel, for instance, which in the early embryo is merely an elongated tube, with indistinct indications

Fig. 10. HEART OF THE EARLY EMBRYO OF THE FOWL

At the 30th, 45th, and 65th hours of incubation. Showing successive stages of involution *s*, venous sinus; *a*, auricle; *v*, ventricle; *b*, arterial bulb.

of three or four dilatations, one in front of another, is in the adult fish folded up into a compact heart, resembling in shape that of the higher animals, though without any divisions between its right and left sides, and transmitting only venous blood. But the parts in front of the heart retain the embryonic character of a vascular loop connecting the arterial bulb, which is the foremost cavity of the heart, with the dorsal vessel or aorta. From the two limbs of this loop arise the vessels of the gills, or organs, which in the fish take the place of lungs, and oxy-

genate the blood by exposing it to the air dissolved in the surrounding water.

It will be observed, therefore, that the modifications of the common Vertebrate type in this class, important as they are in themselves, are yet never such as to violate its general character either as regards the organs severally, or in relation to each other and the whole body.

This combination of variety in details with uniformity in general character is still more clearly brought out, as we pass to the next higher class of Vertebrata, that of reptiles, whose organisation is considerably more complex. From the great diversity, however, among the species of reptiles, it is only by selecting in the first place a particular order, that we can arrive at any definite conclusions. That of the saurians or lizards may in this way be taken as a representative of the class, and their type of conformation subsequently modified, so as to apply to the serpents and tortoises.

Now the most obvious difference between the saurian reptiles and fishes, is the alteration in the general contour of the body, by the introduction of a neck between the head and trunk, and the greater attenuation of the tail, as well as the ampler development and characteristic position of the two

pairs of limbs. By the introduction of a neck, the shoulders, or points of connection of the fore-limbs with the spine, are removed from the back segment of the head, as in fishes, to the anterior part of the chest. The hind limbs again are no longer attached merely to the soft tissues, and therefore liable to vary in position in different species, but are fixed to the spine by the bony girdle of the pelvis, at the point where the alimentary canal terminates, so that they serve to give greater distinctness to the commencement of the tail. The two pairs of limbs are thus placed as bases of support at opposite extremities of the trunk, which at these points has its hæmal arch much more completely ossified than in the case of fishes, which have neither a pelvis for the attachment of their hind-fins, nor a breastbone at the anterior part of the trunk. The intermediate region or abdomen generally has its bony walls very defective, though, as has been already mentioned, there are in certain reptiles — as the crocodile (*fig.* 1) — well developed abdominal ribs and sternum.

Scarcely less important in its bearing on the general contour of the animal, is the absence in reptiles of those prolongations of the skin-skeleton along the middle line of the body, in the form of fins, which are such marked features in the external conformation of the fish. In a few lizards there is, indeed, a small dorsal

crest of this nature, but there never is any on the ventral surface, or at the tip of the tail; unless we admit as an exception the tadpole or larval form of Batrachians, which in this, as in other respects, come forth from the egg with many of the characters of fishes. In fact — with the exception of the tortoise tribe — the skin-skeleton is not generally anywhere much developed in reptiles; the body being covered with horny scales, which rarely have any bony core.

When we pass to the interior of the body, we find the nervous and alimentary systems arranged on the same general plan as in fishes, although more highly developed; we observe especially, that the nervous masses of the brain are larger in proportion to the spinal cord, and that the alimentary canal is longer and more convoluted.

In the vascular system, on the other hand, there is a wide difference between fishes and reptiles. The gills of the former, which are offshoots, as we have seen, from the vascular loop in front of the heart, are replaced as aërating organs by the lungs, which are rather diverticula from the heart itself. The gill and lung indeed, though performing the same office, are not corresponding, or, as the zoologist says, *homologous* organs. This appears from their mode of formation in the embryo, after the ventral and dorsal vessels,

with their connecting loop, are already marked out. The subsequent development in the fish principally affects the loop, from both limbs of which arteries are thrown out to supply the gills; while the simple heart is the result of a comparatively slight transformation of the ventral vessel. In the air-breathing Vertebrate, again, the latter organ is the principal seat of change; it becomes divided into right and left halves, by a median partition; the cavities of the right side—like the single heart of the fish—propelling onwards the venous current of blood, while those of the left side are superadded to receive the aërated blood from the lungs, and transmit it through the body at large. But the division of the chambers of the heart is never so completely effected in the reptiles as in the higher Vertebrata; there always remaining some communication between the two sides of the organ. An interesting link of connection between this arrangement and that characteristic of fishes, is furnished by the newts, frogs, and other Batrachian reptiles, already noticed as presenting in their tadpole state many peculiarities of the inferior class. These animals in the first instance develope gill-tufts from the sides of the vascular loop, and subsequently pulmonary vessels in connection with the left side of the heart. In the majority of the

order, the gill structures disappear, when the circulation is established through the lungs, but in a few

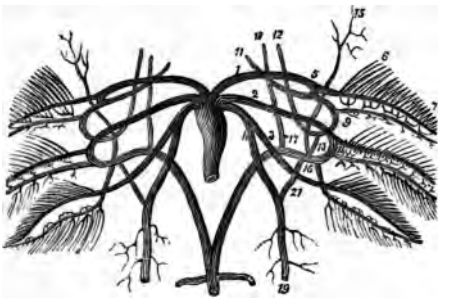

Fig. 11. ARTERIAL BULB OF THE TADPOLE OF THE NEWT

At the commencement of arterial respiration, with the vessels given off to the branchiæ or gills on each side. Below is seen the descending aorta, formed by a reunion of the lateral branches. 19, artery to the lung.

species they are permanent, so that both kinds of aërating organs coexist in the same animal, though generally of diminutive size; thus, in the Proteus, the gills are represented by small inconspicuous tufts on each side of the neck, and the lungs by small vesicles at the ends of two very slender air-tubes. But, indeed, even in true fishes, such organs may in one sense be said to coexist, the swimming-bladder, with which most of the class are provided, being the homologue of the lung; though from defect of a channel of communication with the external air, and

of special vascular connection with the heart, it is in general incapable of performing any respiratory function.

Hence the principal peculiarities which distinguish the lizard-like reptile from the fish, are:—

1. The modification of the skeleton by the introduction of a neck and a breastbone, by the attenuation of the tail, and by the amplification of the two pairs of limbs, and their fixation in their respective positions.

2. The absence of large median fins.

3. The alterations just noticed in the vascular and respiratory organs.

But of these differences, the first holds to the full extent only in the case of the lizard-like reptiles. In the serpent tribe (*fig.* 2), the deviations from the characteristic structure of the fish's skeleton are much less marked. There is no sternum to complete the hæmal arch, while all the vertebræ are furnished with ribs, from the upper part of the neck to some way on in the tail, so that neither of these regions is very distinguishable from the trunk. In the entire animal, indeed, the vascular loop in front, and the posterior orifice of the alimentary canal behind, serve to mark the limits of the trunk, but in the skeleton it is impossible to define them exactly, from

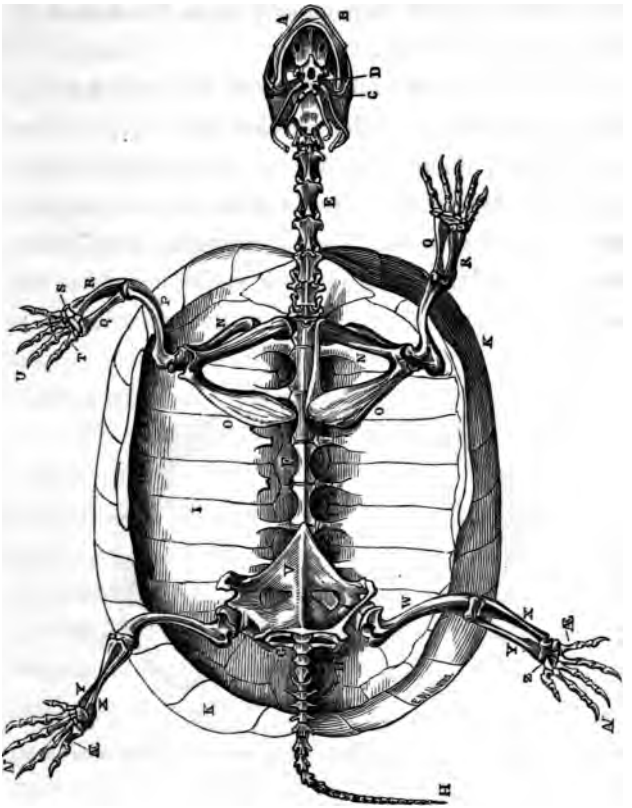

Fig. 12. SKELETON OF THE TORTOISE WITH THE BREAST-PLATE REMOVED.

A, B, C, D, bones of the skull; E, cervical vertebræ; O, N, bones of the shoulder; F, dorsal vertebræ; V, bones of the pelvis concealing the sacral vertebræ; H, caudal vertebræ; Q, R, T, S, U, bones of fore-limb; X, Y, Z, Æ, bones of hind-limb; I, K, annular segments of external skeleton.

the total absence of limbs—a particular in which the organisation of the serpent falls even below that of the majority of fishes.

But if the serpent falls short of the typical structure of the reptile by deficiencies in its bony framework, which has neither ribs nor sternum, the tortoise (*fig.* 12) obviously deviates still farther by excess of osseous development. This affects mostly the skin-skeleton, and shows itself, not as in fishes, by the evolution of median fins, but by the formation of a

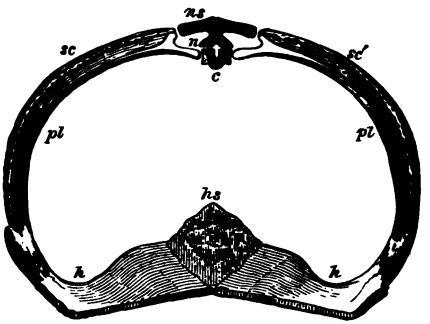

Fig. 13. SECTION OF THE BONY CASE OF A TORTOISE (*Orr's Circ. Sci.*).
Showing the great extent of tegumentary ossification, in which the bones of the internal skeleton, *pl*, *n*, *c*, *pl*, are, as it were, lost.

sort of bony case, enveloping the body to an extent varying with the species. This external skeleton possesses the same segmented character as has been already noticed in the armadillo, and a few other

Vertebrata. The internal skeleton has a proportionally small development, and is in a great degree lost in the outer.

Yet it is to be observed that none of these modifications violate the general characteristics of the Vertebrate type, either in the conformation of its leading systems, or in their mutual relations. We still have the spinal column with its dorsal canal containing the nervous cord, and its hæmal canal containing the alimentary tube and the vascular system. We still find the latter consisting of a large ventral vessel or heart, which communicates with a dorsal aorta by a vascular loop.

The general plan of construction just laid down as characteristic of the typical reptiles, applies in a great measure to all terrestrial quadrupeds; only as we pass upwards from it to the Mammalian class, we find the regions of the body more distinct in their respective peculiarities, and in consequence more clearly marked off from each other. Thus, though the trunk of the crocodile is divisible into the same regions of thorax, abdomen, and pelvis as that of a Mammalian, yet the middle tract or abdomen, which in the skeleton of the latter is a complete blank, has its bony walls developed to such an extent in the former (*fig.* 1), that the hæmal aspect of the trunk

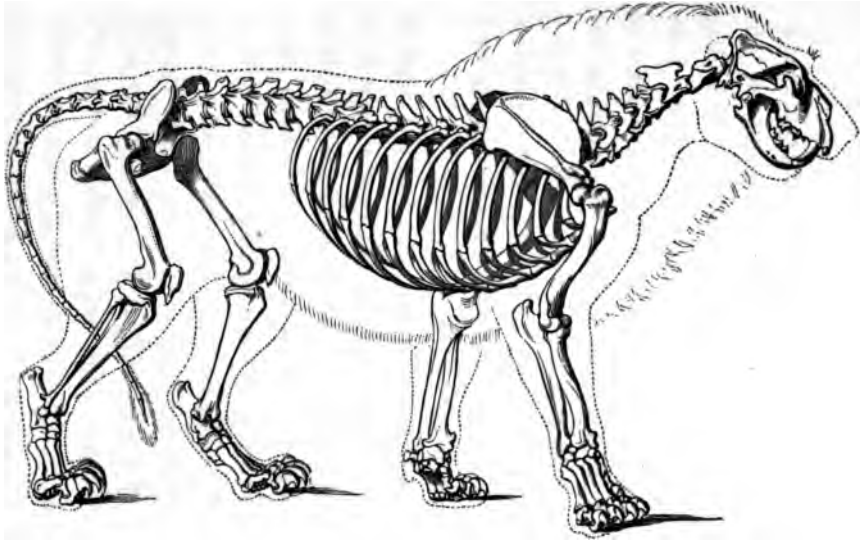

Fig. 14. SKELETON OF THE LION (*Felis Leo*).

Showing the seven vertebræ in the neck, the vacuity in the abdominal region, and the absence of neural and hæmal arches in the tail; showing also the increased development of the limbs.

has one uniform cage-like appearance through its whole extent. Still more striking perhaps is the contrast between the round bulky head, slim neck, well-developed trunk, and taper tail of the higher quadruped, and the corresponding regions in the reptile, which grade into each other in a way suggestive of the spindle-shaped body of the fish, were it not for the presence of limbs, which, dwarfed and puny as they are, serve to mark off the different regions, and have besides the structure of true legs, not of fins.

The strongly-marked character which attaches to some regions of the Mammalian skeleton — as the pelvis, and especially the skull — is associated with such transformation and fusion of their bony elements as makes it very difficult to determine the several vertebral segments entering into their composition. In fact, the vertebræ of the skull — as they are now termed by naturalists — are so devoid of any apparent resemblance to the parts going under the same name in other regions of the body, that we need not wonder that their recognition as corresponding elements is of so late a date. The prominent character of the Mammalian skull is the capacity of its neural cavity in adaptation to the greatly developed brain, which has now exchanged its appearance of being merely the anterior end of the spinal cord

for that of the great centre of the nervous system, of which the cord is but a sort of outlying appendage.

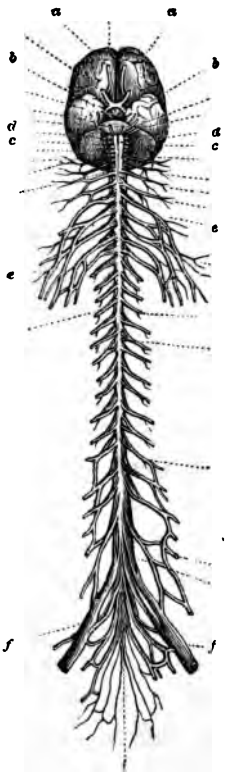

Fig. 15. NERVOUS AXIS OF MAMMALIA.

Superiorly the brain proper; *a*, *b*, *c*, its anterior, middle, and posterior lobes, the latter covered by the cerebellum or lesser brain; *d*, inferiorly the spinal cord, with the nerves given off on each side; *e*, great nerves to fore-limbs; *f*, great nerves to hind-limbs.

The increased size of the trunk is due to the amplification of its hæmal canal, required for the accommodation of the heart and lungs, as well as of the alimentary canal, which are all more highly developed than in the reptile class. The heart, moreover, and its associated vessels, present some very distinct peculiarities. The division of the ventricle into two is now completely carried out, and concomitantly with this one limb of the vascular loop of the embryo altogether disappears; the other, known as the arch of the aorta, becoming in the fully formed animal the sole channel of communication between the heart and the dorsal vessel.

The Mammalian conformation is remarkably constant to one type; a point the more observable from the species having a very wide range of habitat. Some are denizens of the ocean as much as fishes, others destined for an aërial life, while the majority are terrestrial; yet their adaptation to such varied conditions of existence is effected by comparatively trivial modifications of the general type.

The fore-limbs of the bat *(fig.* 16*)*, for instance, by which it is able to flutter through the air like a bird, differ from those of other Mammalia only in this, that the finger bones are of very great length, and that a fold of skin is stretched over them in the form of a delicate web, and is continued along the sides of the

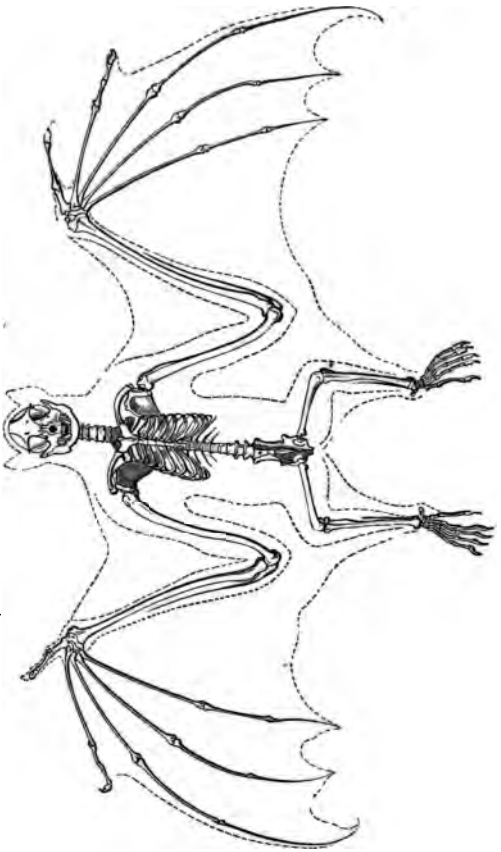

Fig. 16. SKELETON OF THE TAIL-LESS BAT (*Pteropus*).

Showing the attachment of the alar membrane to both extremities, and particularly to the elongated finger bones of the fore-limb.

body, so as to connect them with the hind-limbs and tail.

In the Cetacea, again, — that is, the whales, porpoises, and other such animals, — though they depart so widely from the ordinary form of Mammalia as to go under the popular name of fishes, the only real interference with the type consists in the absence of hind-limbs; their fore-limbs, which have very much

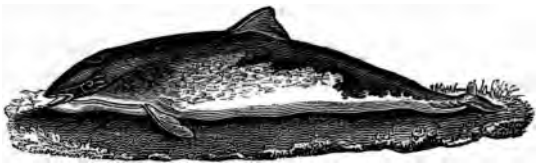

Fig. 17. THE PORPOISE (*Phocena communis*).

Showing the resemblance to a fish in the general outline, and in the presence of a tegumentary appendage like a median dorsal fin.

the appearance and fulfil the office of fins, having really the same bony framework and general internal structure as the fore-legs of land animals; while the apparent want of neck is due, not to this region being deficient in the skeleton, but to its concealment by the thick layer of fat under the skin. It is true that the real neck, as represented in the skeleton, is very short, yet it contains the usual number of seven bones.*

* They generally, however, become anchylosed to each other, so that the whole cervical portion of the spine forms but a single piece,

Although, on account of their conformity in general structure, Reptiles and Mammalia have been considered in immediate succession, they are really separated in the scale of organisation by the large and important class of birds, in which the reproduction is oviparous like that of Reptiles, and the circulation on the same general plan as in Mammalia; while in skeletal conformation they depart widely from both, and present a more marked modification of the common type than any other class of Vertebrata. In birds we find the head, neck, and trunk marked off from each other by more distinctive characters than even in Mammalia, for while the neck possesses much mobility, and is often of great length, — containing in the swan as many as twenty-two vertebræ, — the bones of the skull and trunk are so much consolidated, that the sutures or lines of junction are mostly obliterated in the former, while the latter presents throughout the appearance of a closely barred cage. This is due to the absence of a limbar region in the spine, the pelvic bones reaching forward to the chest, while the ribs are continued so far backwards that several pairs may be in connection at once with the sacrum and the sternum. In the skele-

though the outline of its seven original bones may still be distinguished.

ton the tail is much curtailed; the part going under that name in the fledged bird being—like the tail-fin

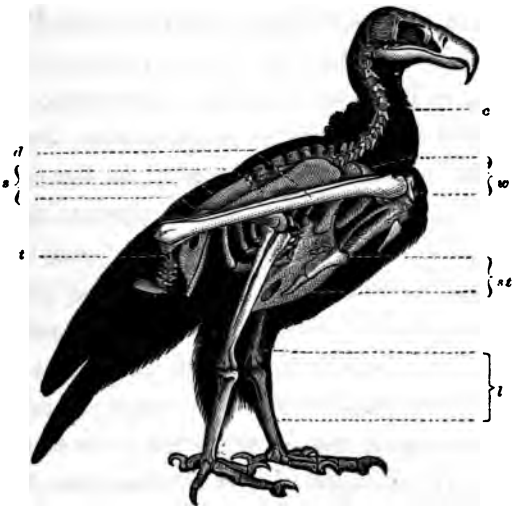

Fig. 18. SKELETON OF THE VULTURE.

Showing the great number of vertebræ in the neck, *c*; the extent to which the sacrum, *s*, is brought forward; the rudimentary condition of the tail, *t*; the open pelvis; the keeled sternum, *st*; the modification of the fore-limbs to serve as wings, *w*; and the balance of the body on the hind-limbs, *l*.

of the fish—a mere extension of the skin-skeleton, or epidermic investment of the body, which in this class is represented by feathers, as it is in Mammalia by hairs. Another peculiarity of the hinder region of the bird is that the girdle of the pelvis is not com-

plete as in other animals, but remains open below. The only exception is in the ostrich family, which deviates also from the normal structure of birds in the rudimentary condition of the fore-limbs.*

These in the majority of the class are well developed, and one of the most characteristic features of the bird is their conversion into wings. As organs of flight they fulfil the same office as the so-called wings of the bat, but in structure they are nearly as unlike them as the large fore-fins of the flying-fish. In the bat, as we have seen, the surface which strikes the air is a fold of skin stretched over the prolonged finger bones, — as is indeed the case also in the fish; whereas in the bird it is formed by the vanes of quill-feathers, mainly supported by bones which correspond to those of the human fore-arm, as will be shown afterwards more at length. The adaptation of the fore-limbs of the bird to the exclusive purpose of flight impresses peculiar characters on the other parts of the skeleton. Thus we find the breastbone of great size, and carried out into a projecting ridge in front, so as to afford attachment to the powerful muscles which move the

* It is interesting to observe that while in this particular the wingless ostrich approaches Mammalia, in the latter class the open pelvis reappears in the skeleton of the bat.

wings. Again, as the whole weight of the body in standing and walking has to be supported on the hind-legs, we find their attachment to the spine strengthened, and brought more over the base of support, by the prolongation forwards of the sacrum and the other peculiarities of the trunk, to which allusion has already been made.

We ought not perhaps to leave this subject without some allusion to the arrangement of parts in the human body. As man, however, — so far as his bodily organisation is concerned, — is included by zoologists among Mammalia, the remarks on their conformation will apply in general to our own species. In fact, the *bodily* peculiarities which distinguish man from the higher of the inferior animals, though numerous, are not of a very prominent kind. His great diagnostic character lies in his mental constitution, in the endowment of the spiritual element of his nature with those moral and reflective powers which raise him so far above the level of the brutes; while the corporeal differences are of so secondary a kind that some naturalists have included him in the monkey tribe; and even Linnæus, the great reviver of natural history, placed him in the same general order with the apes and the bats.

All these corporeal differences, be they great or

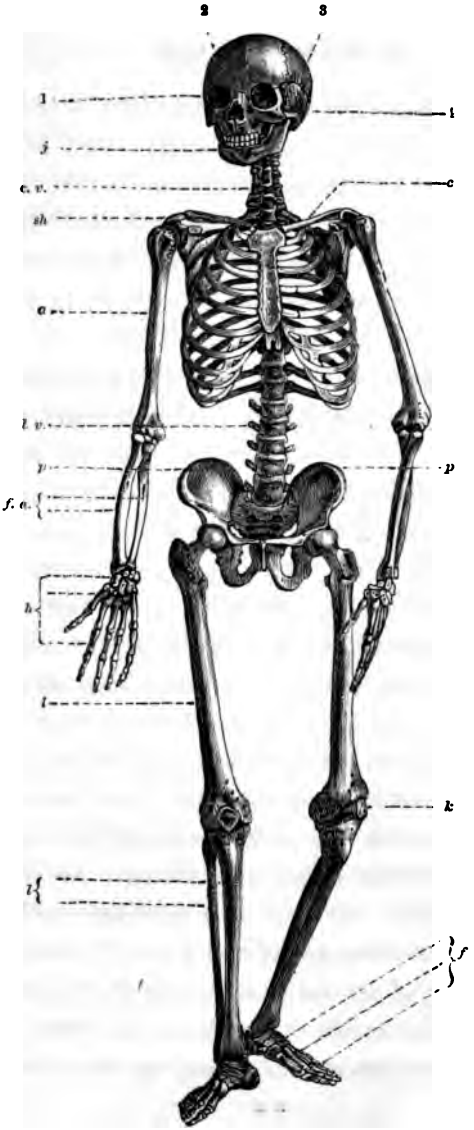

Fig. 19. HUMAN SKELETON.

Showing the large and globular brain-case formed by the neural arches of the four vertebræ of the skull, 1, 2, 3, 4; the parallel jaws, *j*, which do not form a muzzle, as in the lower animals; the thorax or chest, *c*, flattened in front; the horizontal pelvis, *p p*; the greatly developed lower limbs, *l l*; and the peculiar modifications of the bones of the hands, *h*, and feet, *f*.

small, seem to be reducible to two heads. They are connected either with the vastly greater development of the brain of man, or with his upright posture. Some of the latter are merely verbal, as the substitution of the terms anterior and posterior for inferior and superior; but others are of a real nature, as the great development of the feet and whole inferior limbs, the horizontal pelvis, the flattened thorax, and many peculiarities of the skull and body generally, on which it is not necessary here to enter, as they do not affect the applications of the general principles before laid down.

This survey of the principal forms of Vertebrate animals — rapid, and, of course, superficial, as it has necessarily been — may yet suffice to show that in none of them is there any real departure from the common type of structure. In all, we have the skeleton internal, and consisting of a jointed bony pillar, with a neural canal above for the lodgment of the nervous cord, and a hæmal canal below, in which lie the circulatory and alimentary organs. In all, the former consist of a ventral vessel or heart, sending the blood forwards, and, by means of a vascular loop, or its remains, communicating with a dorsal vessel or aorta, which lies just below the bony pillar of the spine; while the latter, under the names of the

gullet, stomach, and intestinal tube, occupy the centre of the hæmal canal, and open on the inferior aspect of the animal at both ends; the anterior extremity passing through the loop or arch by which the heart communicates with the aorta.

CHAP. IV.

THE ARTICULATE TYPE, AND ITS RELATIONS TO THE VERTEBRATE.

With the peculiarities of the Vertebrate structure, as pointed out in the preceding pages, we may now proceed to contrast those characteristic of Articulated animals.

Proceeding in the same order as in the survey of the Vertebrate organisation, we are at once reminded that in the Articulata there is no internal skeleton, the support and configuration of the body depending on its shelly or horny integument, which is much more highly developed than in the majority of Vertebrata. It forms, indeed, a true external skeleton, the conformation of which is under as definite laws as that of the internal skeleton of the group last examined.

As the latter is made up of a series of segments termed vertebræ, in each of which we distinguish a solid body and an upper and a lower arch, so the integument of Articulata consists of a series of rings embracing the body, each of which is formed of a

combination of ventral, dorsal, and lateral plates. "Each ring is divided, first, into two arcs, the one superior or dorsal, and the other inferior or ventral; and each arc may present as many as four elementary pieces. Two of these pieces being united in the middle line constitute the *tergum*. The superior arc is completed on either side by two other pieces, known under the name of flanks. The inferior arc presents in its composition an exact counterpart of the superior. Two of the four pieces into which it may be resolved constitute the *sternum*, situated in the median line," * and deriving its name from a fancied correspondence with the breast-bone of Vertebrata. It is, like the tergum, flanked by two lateral pieces. These plates are frequently all run into one, but occasionally some of them are connected only by membranous folds, allowing a slight degree of motion between the pieces.

The segments, rings, or annules are connected together in the length of the animal by similar folds, —the anterior generally slightly overlapping the posterior, so that they form in the aggregate a sort of hollow column, which contains the muscles and viscera, and has a certain amount of flexibility in all

* Milne-Edwards, Cycl. Anat. and Phys., art. Crustacea, vol. i. p. 754. Audouin, Ann. des Sc. Natur. tom. i.

directions.* In the case of some worms, each segment has lower and upper appendages on both sides: in insects the latter are confined to two segments, and take the form of wings, while in other classes they are wholly wanting; but the inferior appendages, though generally restricted in number, are rarely absent, and some of them are in most cases developed into well-formed limbs, encased in the same jointed armour as the body itself.

The segments and appendages are—as in the case of the Vertebrata—variously modified in different parts of the body, in consequence of which the latter appears divided into regions. Three such regions are generally recognised, to which have been applied the names of head, thorax, and abdomen. In the head, or anterior region, as in the Vertebrate skull, the segments are much run together, while the appendages mostly serve as jaws, though with a lateral instead of a vertical movement. In the posterior region, or abdomen, appendages are only occasionally present, as in the lobster tribe, in which they are used for respiration, for supporting the eggs of the animal, and sometimes for other purposes. It is in the middle region, or thorax, where these appendages

* Dr. Dickie compares it to a tunnel with an arched roof and floor.—*Typical Forms*, p. 240.

serve as legs, that they attain their greatest development. In insects, the thorax also bears the wings, of which two pairs are generally attached to the upper aspect of its hinder segments. As the region contains but three, the number of inferior appendages or legs is restricted to six. Other Articulata have generally more segments and legs in this division of the body, but no superior appendages.

The general laws of the development of the segments and appendages of the Articulata were established by Audouin about forty years ago; and since that time the subject has been diligently studied by Edwards, Newport, Darwin, Dana, Huxley and other naturalists. It does not seem necessary for our purpose to go farther into it at present, but some additional details will be given in noticing the peculiarities of the several classes.

As regards the internal organisation, we find that the alimentary canal follows much the same course as in Vertebrata, having two openings on the lower aspect of the animal, of which the anterior or mouth is situated in the head. The principal difference is that, posteriorly, the canal is carried on quite to the extremity of the body, there being no portion behind it to which the name of tail can properly be given.

The main tract of the nervous system has also a

certain correspondence with that of Vertebrata. In both we recognise a longitudinal cord, containing the two great constituents of nervous tissue — that is, the

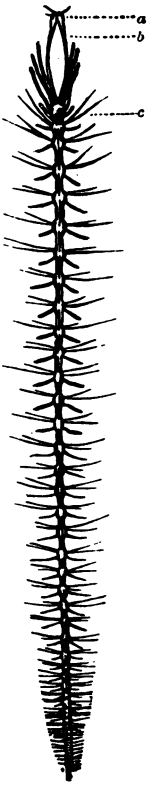

Fig. 20. NERVOUS AXIS OF ANNELIDAN (*Aphrodite*).

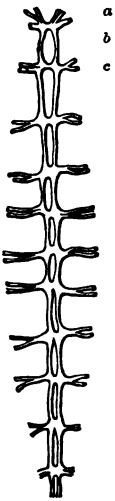

Fig. 21. NERVOUS AXIS OF CRUSTACEAN (*Talitrus*).

Showing the chain of ganglia in the ventral cord, and the constant loop, *b*, which connects the cephalic ganglia, *a*, with the first of the ganglia of the trunk, *c*; showing also the increasing separation of the lateral elements in the lower species.

exciting element which goes under the name of grey or vesicular matter, and the white tubular or conducting tissue. But while, in Vertebrata, the former is present in such quantity as to form a continuous axis, in Articulata it occurs only in ganglionic knots, strung at intervals on a cord of the tubular tissue. There is a farther correspondence in the cord being always a double organ, though more obviously so in the inferior group. In the lower articulated forms, indeed, there may be said to be two cords, united only by their ganglionic enlargements; and even in the higher species a few duplicatures are generally to be found; though the only one absolutely constant is that just behind the anterior ganglion or brain. In the Vertebrate cord, again, though it is deeply grooved along the middle line, the two halves are adherent throughout their whole length, except just behind the brain, the *crura* or footstalks of that organ being separated by what anatomists term the passage from the third to the fourth ventricle. The nervous tract of Articulata runs along the whole lower aspect of the body, and is hence known as the "ventral cord." Anteriorly it is perforated by the alimentary canal, which passes through the loop behind the foremost ganglion, which has just been described, and which, from its relation

to the gullet, goes under the name of the "œsophageal collar."

The circulatory system has also many points of correspondence with that of the higher division of the animal kingdom; only the heart, or organ which propels the blood forwards, is situated on the dorsal or upper aspect, and is much more drawn out than even in the embryo of Vertebrata. It consists of a long, many-chambered canal, running nearly the whole length of the animal; and it communicates in front with a returning channel, on the lower aspect of the body, just above the ventral cord. In some of the more typical species, as centipedes and scorpions, the returning vessel — which is termed by Mr. Newport the supra-spinal artery — has distinctly the character of an aorta. It communicates with the heart by a vascular loop, which embraces the gullet, like the nervous collar, and may quite be compared with the aortic loop of Vertebrata.* Mr. Newport contends for the existence of a similar artery in insects †, but most authors hold that arteries sufficiently developed

* Philos. Transac. 1843, p. 286. Also, W. Lord, in Med. Gaz. Mar. 3, 1838, p. 893.

† Cycl. Anat. and Phys., art. Insecta, p. 980. Med. Gaz. Mar. 17, 1838, p. 973.

to compare with those of Vertebrata are found only in the higher centipedes, Arachnida and Crustacea.* In most Articulata the channels by which the blood is returned to the posterior extremity of the body are without distinct walls, mere vacuities intervening between the internal organs.

In general, it would seem that the stream which issues from the anterior extremity of the heart is divided into two lateral currents, which converge again only at the posterior extremity of the dorsal vessel, though they are connected also at intervals by transverse communications, so as to form a chain of vascular loops, somewhat like the series of nervous loops, united by median ganglia in the ventral cord of the lower species. In some Crustacea the lateral

* In the higher Crustacea the arrangement is different from what obtains in the centipedes and scorpions, but we are not yet in a position to say whether this may not be owing—as in the warm-blooded Vertebrata—to a departure from the original type, as the concentration of the organs in particular regions becomes more marked. Dr. Carpenter suggests a correspondence between the large sternal trunk in the higher Crustacea and the supra-spinal artery or ventral vessel of the scorpion, though he admits it has not been shown to have any connection with the cephalic by aortic arches (Princ. Phys. Gen. and Comp. § 464). But there is a farther difficulty in the difference of function, the anterior branch of the sternal trunk being generally held to carry the blood *forwards*.

currents would appear to coalesce entirely into a median ventral sinus. *

On these data our general idea of an articulated animal would be much as follows: —

On the exterior we have a series of rings, connected together in a longitudinal direction so as to form a cylindrical flexible body, and furnished with jointed appendages attached to their lower, and, though more rarely, also to their upper aspects.

In the interior we have:

1. On the dorsal aspect, a long many-chambered heart, sending the blood forwards, and, in the more

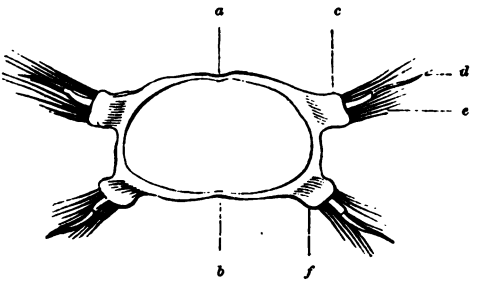

Fig. 22. SECTION OF AN ANNELIDAN.

a, dorsal arch; *b*, ventral arch; *c*, dorsal appendage, bearing a cirrhus, *d*, and a tuft of hairs, *e*; *f*, ventral appendage, similarly garnished.

highly organised species, communicating in front, by a vascular loop, with a sort of ventral aorta.

* Milne-Edwards, Cycl. Anat. and Phys., art. Crustacea, vol. i. p. 776. Siebold's Comp. Anat. by Burnet, p. 339.

2. On the ventral aspect, (and below the said aorta in those species in which it occurs,) a ganglionic cord, with a sort of brain at its anterior extremity, connected with the rest of the cord by a nervous loop.

3. Along the axis or middle line, an alimentary canal, opening at both ends on the lower surface of the animal; the anterior orifice being reached through the vascular and nervous loops, while the posterior is situated at the extremity of the body, beyond the termination of the nervous cord.

The modifications of this common Articulate type need not detain us long, most of them having been already referred to.

The simplest arrangement is found in Annelida, whose segments are so much alike in all parts of their

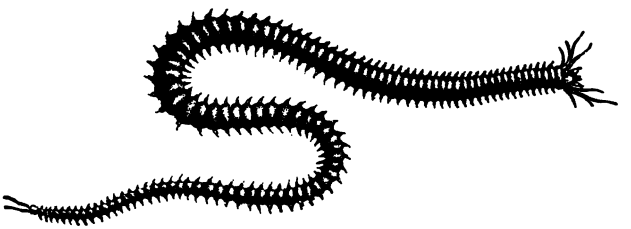

Fig. 23. AN ANNELIDAN, OR MARINE WORM (*Nereis*).

length, that it is with difficulty the head can be made out as a distinct region, and between the thorax and

abdomen, no difference whatever can be recognised. The appendages, when present at all, are of the most rudimentary kind, as small horny plates, bristles, &c.; but in many cases all the segments are so garnished, on their upper as well as on their lower aspects, as shown in *fig.* 22.

According to Milne-Edwards, the anus in Annelida is on the dorsal aspect.* This appears a wide departure from the common type; but in fact the class scarcely belongs to the true Articulata, being rather the highest form of a series of worm-like species, to which this author applies the term Annuloida, *i. e.* animals in which the annular or ringed character is less marked than in the Articulata proper. The absence of articulation in the appendages, is another indication of such degradation of type, as it is called.

In the class of Centipedes, there is but little advance in the distinction of regions: only the head is more clearly indicated than in the last. There is also this difference, that the segments throughout the length of the animal are better defined; and that, while they bear nothing on their upper aspect, they are all furnished with inferior appendages, which in the higher species are developed into well-formed

* Cycl. Anat. and Phys., art. Annelida, vol. i. p. 164.

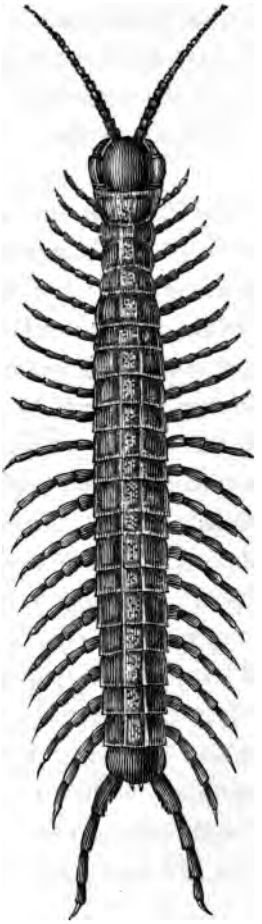

Fig. 24. CENTIPEDE (*Scolopendra*).

jointed limbs, a character expressed with some exaggeration by the names of centipedes, millipedes, myriapoda, &c., applied to the class.

Insects in their larval or caterpillar state have a good deal the external conformation of the inferior Articulata just referred to, but in their highest or winged development, they have the head, thorax, and

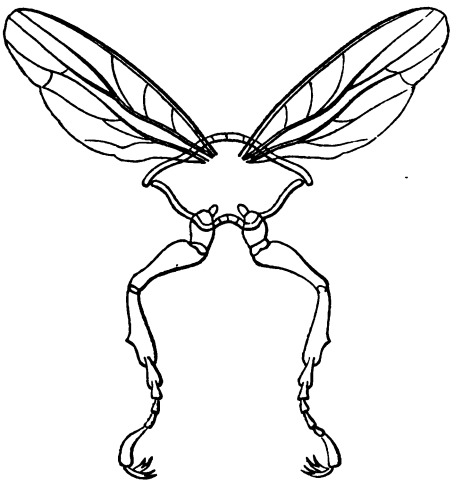

Fig. 25. SECTION OF THE THORAX OF AN INSECT.

abdomen well defined. In the head, though so much condensed that it is commonly regarded as of one piece, Dr. Newport distinguishes four or even

five segments, each with its lateral appendages.* Of the latter, two pairs go under the name of *palpi* or feelers, and two form a sort of jaws, moving horizontally, and variously modified in different species. The hind-jaws, or mandibles, are the best developed in carnivorous insects, and form powerful pincers for

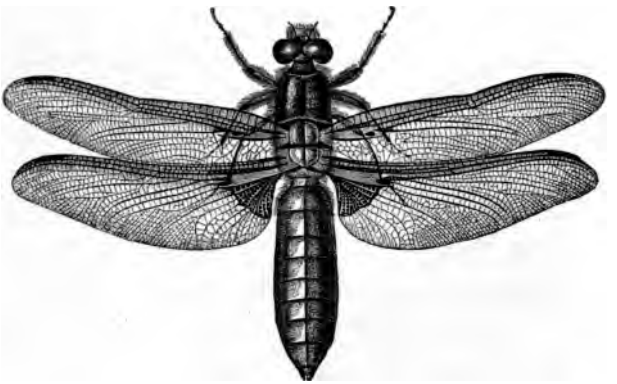

Fig. 26. A SPECIES OF DRAGON-FLY (*Libellula depressa*).

Showing the division into head, thorax, and abdomen. The middle region, or thorax, consisting of three segments, bears all the locomotive appendages; viz. three pairs of legs on its ventral aspect, and two pairs of wings on its dorsal aspect.

seizing and devouring prey, while in the blood-sucking species they rather resemble knives or lancets. In certain cases, Mr. Newport describes them as acting "not from side to side, but with a horizontal move-

* Cycl. Anat. and Phys., art. Insecta, p. 910.

ment from behind forwards, cutting also vertically with a sweeping stroke like the lancets of a cupping instrument."* But it is the fore-jaws, or maxillæ, which are of the most importance in the majority of insects living by suction. It is these which are so remarkably transformed into the proboscis of the butterflies, and other species of kindred habits. Each lateral jaw is drawn out into a sort of thong, grooved along its inner side, and the two are locked together by a peculiar mechanism to form a flexible tube, which is ordinarily coiled up like the spring of a watch, but which at the will of the animal can be at once extended to a length sometimes far exceeding that of the whole body. These species live on the sweet juices of plants; "not a few feed upon wing, and the act is very quickly performed; in the twinkling of an eye the tube is inserted, and the flower is robbed of its sweets. The act of suction by producing a vacuum, which enables the infant to procure nourishment from the breast, is also brought into play, in order that the fluid may rise in the butterfly's proboscis."† The palpi and jaws arise from the lower aspect of the head, but there is at least one pair of appendages connected with its dorsal surface, viz. the jointed tactile fila-

* Dr. Dickie, Typical Forms, p. 263.

† Ibid. p. 262.

ments known as antennæ. Perhaps also the eyes should be considered as superior appendages, though they are never truly stalked in this class. Both are connected with the back segments of the head. The great development of the inferior appendages of this region causes the anterior nervous ganglion or brain, whose typical situation is in front of the mouth, to be tilted up so as to occupy a position on the dorsal aspect of the head.*

The thorax of insects contains three segments, all of which bear legs, while the two posterior have also upper appendages in the form of wings, which are present with very few exceptions throughout the class.

The segments of the abdomen, variously estimated from eight to eleven, bear no appendages, except occasionally at the terminal extremity. Of this nature are the sting of the bee, the ovipositor of the gall-fly, the caudal fork of the earwig, and probably the terminal filaments of the spring-tail and some other insects.

In the class Crustacea (the crab and lobster tribe), many of the lower species have somewhat the uniform character of the centipede; as we see in the wood-louse, or sand-hopper, and, to a certain degree, even in the lobster.

* Goodsir, in Ed. New Phil. Jour., Jan. 1857.

The normal number of segments is said to be twenty-one, seven in each region*; but, in the higher species, the head and thorax are so run together as to form a rounded body, in which all trace of segmentation is lost, while the abdomen, stripped of appendages and doubled up under the body like a tail, may altogether escape the notice of a casual observer. This is the arrangement with which we are familiar in the common species of crab.

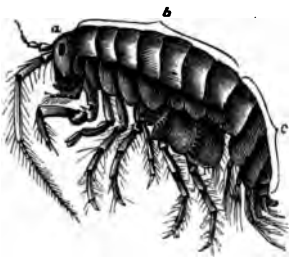

Fig. 27. A CRUSTACEAN (*Talitrus*, or Sandhopper).

Showing the division into the three regions of head, *a*; thorax, *b*; and abdomen, *c*; the latter two containing each seven segments.

The eyes differ from those of insects, in being often placed on footstalks. Indeed neither they nor the antennæ can well be considered true homologues of the parts so named in the last class, though they perform the same offices and are attached to the head;

* Milne-Edwards, Cycl. Anat. and Phys., vol. i. p. 754.

as, like all the appendages of the Crustacea, they are held to arise from the lower aspect, and are connected with the foremost segments of the region.* The other head segments bear pairs of horizontal jaws of various forms.

The anterior thoracic segments bear appendages termed foot-jaws, as forming a transition to the true feet, connected with the hinder divisions of that region. The pincers with which some of the anterior thoracic limbs are furnished are a conspicuous feature in the organisation of the higher Crustacea. The abdominal appendages are generally but little developed, except that in the swimming species those in connection with the terminal ring are expanded into a large tail-fin. The appendages generally are more complex than in insects, as the main stem in its most perfect state of development bears two accessory pendicles, of a variable number of joints, the palp and flabellum.† In the abdominal limbs these sometimes serve for respiration.

To the Crustacea belong the singular tribe of Barnacles, so long a source of perplexity to naturalists. In general they were referred to the Molluscan group,

* Milne-Edwards, op. cit. vol. i. p. 758.

† "It but rarely happens, however, that these three organs exist simultaneously."—*Milne-Edwards*, op. cit. vol. i. p. 758.

and there was equal dubiety in regard to the relations of the several parts of the body. As is remarked by Mr. Darwin, "that which is the anterior end in the eyes of one naturalist is the posterior end in the eyes of another; so with the dorsal and ventral surfaces." * The true homologies have now been clearly indicated by Darwin in the work just quoted. He has distinctly shown that the active crab-like larva, in the course of its metamorphosis into the odd-looking and

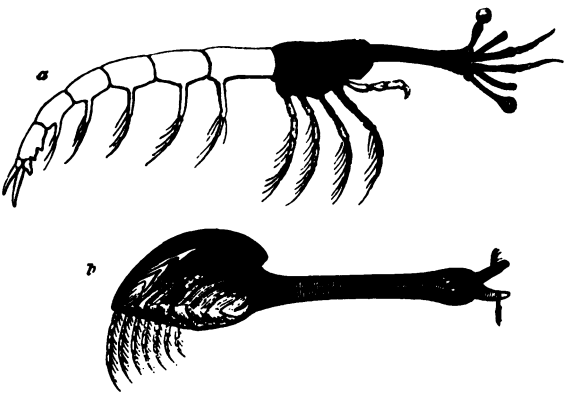

Fig. 28. *a*, A CRUSTACEAN (*Leucifer*).
The head and thorax, which are shaded, correspond with the next.
b, A BARNACLE (*Lepas*).
The eyes and antennæ disappear in the adult stage, but their remains occupy the position here indicated at the base of the pedicel.

stationary barnacle, has the anterior segments of the head converted into the stalk of attachment, which

* Monograph on the Cirrhipedia (Ray Soc.), vol. ii. p. 125.

in some cases is greatly elongated, and which still furnishes traces of the eyes and antennæ. At the same time, a multivalve shell, originally developed in the third segment of the head, is extended round the remaining divisions of the body, which are principally thoracic, those of the abdomen being rudimentary.* Darwin's explanation of the singular dislocation of some of the head segments in the course of development †, reminds one of Owen's views in regard to the displacement of the anterior extremity of the higher Vertebrata by the interpolation of the neck.

The following tabular view of the segments and their appendages in the normal Crustacea and Barnacles, may serve to make their relations more intelligible ‡:—

Appendages in Crustacea.	Regions and Segments.	Appendages in Barnacles.
	(*Head.*)	
Eyes	1	Eyes and antennæ distinct in the larva.
Antennæ (2 pairs)	2, 3	
Jaws (3 pairs)	4—6	Jaws (3 pairs).
Foot-jaws (3 pairs)	7 (*Thorax.*) 8	Wanting.
Feet (5 pairs)	9 10—14	Cirrhi (6 pairs).
	(*Abdomen.*)	
Variously modified	15—17	Rudimentary.
	18—20	These segments wanting.
Tail-fin	21	

* Darwin, op. cit. vol. ii. pp. 13, 111. † Ibid. vol. ii. p. 125.

‡ M'Cosh and Dickie, Typical Forms in Creation, chap. vii. p. 244, 250; Darwin, op. cit. pp. 111, 125.

A like retrograde course of development, if we may so term it, characterises another tribe of Crustacea, which live as parasites on the bodies of fishes and whales. In their early stage they are minute active creatures like water-fleas, but afterwards become singularly deformed by the inordinate development of certain segments and appendages of the body at the expense of others. In this way are formed the peculiar arms, suckers, and other organs of adhesion, characteristic of the tribe.

There remain now of the more typical Articulata only those which are referred to the class Arachnida. In some cases there is a general resemblance between this class and the last. Thus in the scorpion we have large pinching claws as in Crustaceans, only they are connected, not with the thorax, but with the head. The bulk of the body, too, is formed of the head and thorax run together, while the abdomen forms merely a sort of posterior appendage, as in the crab. It is, however, a much more conspicuous organ. Being of great length and much attenuated, we cannot wonder that it should go popularly under the name of a tail, from its obvious resemblance to that part in Vertebrata. In the spiders again belonging to the same class, owing to the softness of the integument, there is no appearance of segmentation. The body is

simply divided into two rounded masses, of which the posterior, which has no appendages, represents the

Fig. 29. SCORPION.

Showing the attenuated tail-like abdomen.

abdomen, while the anterior consists of the head and thorax run together. The thorax is supposed to be

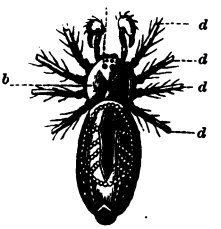

Fig. 30. ARACHNIDAN (*Pholcus rivulatus*).

Showing the rounded abdomen, *a*; and cephalothorax, *b*: the latter bearing in front the palpi, *c*; and laterally the four pairs of legs, *d d d d*.

made up of four segments, from the walking limbs of the animal being eight, a number as constant in this class, as six is in the class of Insects.

Along with these variations in the external skeleton of the several classes of Articulata, we find comparatively little difference in the arrangement of the internal organs. They are of course more rudimentary in the lower than in the higher species, but this is much more apparent within the limits of each class, than when we compare one class as a whole with another. Indeed, making due allowance for the very undeveloped condition of many Articulata, the common type appears quite as definitively carried out in this as in the Vertebrate division of the kingdom; or, if there be any exception, it is only as concerns the vascular system.

We are now in a position to institute a comparison between the plans of construction characteristic of these two leading forms of animal organisation, as represented in section in Plates II. and III.

Firstly, in regard to the skeleton, it appears from what has been already said that in both cases we have the viscera enclosed in hollow flexible cylinders, formed of numerous rings placed one before another, and that it is with the exterior of these rings, on their lower aspect, that the jointed limbs of the animal are connected symmetrically in pairs. We have also in both cases indications of distinct regions, such as head, thorax, and abdomen, dependent on corresponding peculiarities in the conforma-

tion of the rings belonging to certain parts of the series.

But, on the other hand, there are at least two points of very obvious difference. Thus while in Articulata the skeleton, being external, has for its office to envelop the whole body, in Vertebrata its use is more special, viz. to invest the peculiarly vital organs, those of digestion, circulation, and innervation. The muscular system, being excluded from its embrace, is placed on its outside, so that, as regards the body at large, the skeleton is internal. But in a more particular manner the Vertebrate skeleton is the envelope of the nervous system, for the lodgment and support of which the peculiarities in its construction appear to be specially designed. While in Articulata there is but one series of rings in the skeleton, enclosing in a single cavity the nervous cord, the alimentary and circulatory organs, and the general muscular system of the animal, in Vertebrata there are two such bony canals, hæmal and neural, separated by the solid pillar of the spine; one of these being for the special accommodation of the nervous cord, and the great office of the underlying vertebral column being to give additional support to that precious organ.

In the thorax of some Crustacea, a sort of imperfect neural canal is indeed formed, more or less distinct from the general cavity of the body, by pro-

jections which the plates of the ventral surface send inwards for the attachment of muscles. But, as Owen remarks, "their relation to the nerve-trunks seems to be accidental, depending upon the position of the muscular masses to which they give attachment, and which office is the essential condition of their existence. For this purpose the processes of the exo-skeleton of Insects and Crustacea must go inwards, and thus they happen to protect certain parts of the nervous system." * Above all there is no central pillar or main shaft intervening between the two great cavities, hæmal and neural, and forming a common point of support for their encompassing arches. This is the great and peculiar characteristic of Vertebrata.

The nearest approach which is made by any Vertebrate animals to the skeletal arrangement characteristic of the Articulata, is that which has been noticed as obtaining in the order of Tortoises. In all of these the external skeleton is well developed, and in the land-tortoises especially it forms a general envelope for the trunk (*fig.* 13.), which, like that of the Articulata, encloses all the soft parts of the body, muscles as well as viscera; and which has also the same

* Compar. Anat. i. 166, ii. 22 (orig. edit.).

segmented character, though the joinings or sutures connecting the rings do not admit of motion, the whole forming a compact case, so much resembling the shell of a crab that the name *Carapace* has been applied to both.* The internal skeleton, again, is quite rudimentary, and adheres to the interior of the other, from the nondevelopment of any investing layer of muscles. There is here certainly a considerable resemblance at first sight to the arrangement already noticed as occurring in the thorax of certain Insects and Crustaceans. Still the Vertebrate character of the skeleton is indicated, not only by the ordinary arrangement obtaining in the head, neck, and tail, as well as in the limbs (none of which have any osseous envelope), but by the bodies of the vertebræ being distinctly continued even in the trunk, so as to divide in the usual manner the neural from the hæmal canal.

As regards the arrangement of the internal organs, we observe that the Vertebrate and Articulate types agree in the following particulars:—

* In the *Cistudo*, however, the fore and hind segments are movable; so that when the animal withdraws its head, tail, and legs into its shell, they admit of being folded like lids against the apertures; a peculiarity which has gained for the species the name of Box-Tortoise.

1. In the central tract of the nervous system consisting of an anterior mass or brain situated in the head, and a cord running from this backwards, along one of the aspects of the body, to its posterior extremity.

2. In the heart, or vessel which propels the blood forwards, being a chambered organ, situated on the aspect opposite to that occupied by the nervous cord, and communicating by a vascular loop with a returning vessel or aorta, which lies on the aspect of the nervous cord next the heart.

3. In the alimentary canal passing from the mouth backwards, first through the vascular loop or its representative, and then along the axis of the body, in the intermediate space between the heart and aorta, to its terminal orifice, situated like the anterior one on the inferior aspect of the body.

There is therefore a very circumstantial agreement in the conformation and mutual relations of all these internal organs; but, as already mentioned, there is at the same time a striking contrast in their relations to the body at large. Thus in Vertebrata the dorsal or upper aspect is also the neural, or that occupied by the nervous cord, while the opposite, that is the ventral or lower aspect, is also the hæmal, on which is situated the heart. In Articulata again, these rela-

tions are inverted, the nervous cord occupying the inferior or ventral aspect, and the heart being placed on the upper aspect or back. From the ventral position of the cord in Articulata, a nervous collar is required, as well as the vascular loop or arch which suffices in Vertebrata, to admit of the alimentary canal communicating with the mouth, as this cavity must open inferiorly on the ground, the great source of the animal's food. Posteriorly, the barrier which the cord interposes between the alimentary canal and the inferior surface is surmounted by the latter being carried quite round the former, and made to terminate in an orifice at the very extremity of the body. Hence, as already explained, there is no part corresponding to the tail of Vertebrata, which is properly that portion of the axis of the animal lying beyond the termination of the digestive canal. It is true that in the scorpion (*fig.* 29.), the crab, and some other Articulata, the terminal region of the body assumes very much the taper character of a tail, but it always differs from the part properly so called in this, that it contains a prolongation of the alimentary canal, which terminates only at its extremity, so that it is nothing else than an attenuated abdomen.

Hence, putting out of view the differential characters of the skeleton, and considering only the relations of

the internal organs, we might imagine the conversion of a vertebrated into an articulated animal by turning it on its back, and carrying the gullet through a perforation at the base of the brain to a new mouth somewhere on the back of the head, while posteriorly the tail would have to be cut off, and the lower part of the canal turned round its stump to a new anus at its root. The very point where we should make the anterior perforation may be said to be indicated by the canal between the limbs of the brain to which anatomists give the name of the passage from the third to the fourth ventricle, and which may perhaps be considered the homologue of the œsophageal collar of the nervous cord of Articulata.

Subjoined is a tabular statement of the points of agreement and contrast, as now indicated, between these two primary groups of animals.

THE POINTS OF AGREEMENT LIE,

1. In the longitudinal extension of the axis of the body between the two extremities of the alimentary canal;
2. In the symmetry of the parts on the right and left sides of the axis;
3. In the division of the skeleton into segments by lines perpendicular to the axis;
4. In the body being generally furnished with a series of jointed appendages on its right and left sides;

5. In the following disposition of the internal organs:

On one aspect (which may be termed *hæmal*) is situated the heart, or contractile vessel propelling the blood forwards.

On the other (*or neural*) aspect, are situated:

I. A series of ganglia, either strung or fused together into a nervous cord, with at least one loop behind the foremost ganglion or brain.*

[II. On the aspect of the nervous cord, which looks towards the heart, the aortic continuation of that organ communicating with it by a vascular loop, and carrying the blood backwards.]†

In the intermediate line, along the axis of the body:

The alimentary canal, opening before and behind, on the lower surface which bears the limbs.

THE POINTS OF CONTRAST LIE,

1. In the skeleton, being—

In Vertebrata, mainly internal;

In Articulata, wholly external.

2. In the ventral or lower surface (on which are situated the limbs and the two orifices of the alimentary canal,) coinciding—

In Vertebrata, with the hæmal aspect;

In Articulata, with the neural aspect.

---

* This loop is assumed to be represented in Vertebrata by the passage from the third to the fourth ventricle (*iter a tertio ad quartum ventriculum*); in Articulata, by the œsophageal collar.

† The characters founded on a median artery, returning the blood backwards, are bracketed, as applying only to some species of Articulata; while the loop is converted into a single arch in the adult state of the higher Vertebrata.

3. In the anterior end of the alimentary canal reaching this surface by traversing —
   In Vertebrata, a vascular loop;
   In Articulata, [both a vascular and] a nervous loop.
4. In the posterior end of the alimentary canal reaching the same surface —
   In Vertebrata, short of the neuro-vascular spine, which is prolonged as a *tail*;
   In Articulata, beyond the termination of the nervous cord, and at the extremity of the body; so that there is no true tail.

CHAP. V.

THE MOLLUSCAN TYPE.

On the typical construction of the third great division of animals the Mollusca, but few remarks will here be offered. The group is undoubtedly a natural one: yet this is not obviously indicated by such a prevailing constancy of plan as is presented by Vertebrata and Articulata, in the disposition of the several parts of the body external and internal; it is rather to be inferred from a certain uniformity of character in the organs themselves, and from the interior systems predominating, in the general development, over the parts on the exterior concerned in locomotion.

To such an extent does this obtain, that in the case of some species the animal has been compared to a mere bag of viscera; while, with few exceptions, the locomotive powers are of so low a grade, in consequence of the small development of the organs ministering to their performance, that the term *sluggish*, derived from one of the species, may not

inaptly express the general character of the group in this respect.*

The circumstance, farther, that a skeleton or supporting framework of hard materials is frequently absent, and that, even when present, it is rather moulded upon the soft tissues than they upon it, is of itself adverse to the marked development of a distinct type of construction.

But Mr. Huxley †, who has discussed at length the

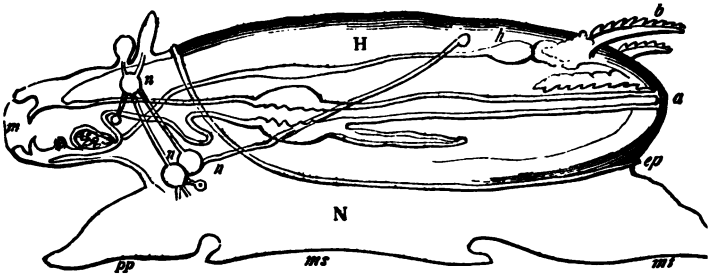

Fig. 31. COMMON PLAN OF MOLLUSCOUS ANIMALS (*after Huxley*).

H, hæmal aspect; N, neural aspect; *pp*, *ms*, *mt*, fore, middle, and hind foot; *ep*, epipodium, or upper foot; *h*, heart; *n n n*, nervous ganglia and collar; *m a*, alimentary canal; *b*, gills, or branchiæ.

* Carpenter, Principles of Physiology, General and Comparative, § 297a.

† Mr. Huxley's papers are contained in the Trans. Roy. Soc. 1853, and in Knight's Eng. Cyc., art. Mollusca. A summary of his conclusions is given in M'Cosh and Dickie's "Typical Forms and Special Ends in Creation," chap. vi.

homology of Molluscous animals, is of opinion that a common plan is to be recognised in their organisation, though more masked in special forms, than is the case in the groups already considered. The Molluscan plan of construction is regarded by him as consisting of two main regions, whose line of junction is marked by a constriction of the body, and sometimes also by a peculiar fold or projection, to which he gives the name of *epipodium* or upper foot. The regions he terms hæmal and neural, because in the former is situated the heart propelling the blood forwards, and in the latter the principal nervous centres. The mouth is placed at one extremity of the neural region, having in the higher species the character of a distinct head, and bearing special organs of sensation: while the anal orifice is situated in the opposite or hæmal region, the gullet passing through a nervous collar which lies behind the mouth, and connects the anterior ganglia, as in Articulata.

There is a correspondence, farther, with the Articulate plan, in the neural aspect being also the ventral, or that connected with the apparatus of locomotion. But the resemblance stops here. The heart, though dorsal is not drawn out into a tube, and the nervous ganglia, instead of being strung on a ventral cord, are irregularly distributed through the system; in short,

neither the viscera nor the body at large are elongated in the direction of a common axis, while the latter, except in certain transition forms *(Chiton*, &c.), presents no trace of segmentation, nor is it furnished with any jointed limbs.

Locomotion is effected by a fleshy disc on the neural aspect called the foot, or sometimes rather by elongated marginal lobes of its contractile substance, which go under the name of *tentacles*, and form the only limbs which occur in connexion with this type of organisation. The head also generally bears tentacles in connexion with the organs of sensation, and in many species papillæ are developed on the hæmal aspect to serve as gills. In some species of the *Nudi-*

Fig. 32. EOLIS (*dorsal view*).

Showing the numerous tentacles on the back, and the two pairs on the head.

branchiate group these are so multiplied as to suggest the idea of the spiny back of a hedgehog.

Probably too of the same general nature is the *mantle*, a free fold of skin arising from some part of the hæmal aspect, and reflected over the body to an

extent varying with the species. When a hard framework is present, it is developed on the exterior of this mantle, and mostly assumes the form of a shell of one or two valves. Such a shell very generally invests the body of the embryo, and, though in some species it afterwards disappears, it is more commonly a permanent structure, enlarging with the growth of the animal, by successive additions to its margins.

A very marked peculiarity in the development of the Mollusca, is the disproportionate increase of some part of the hæmal region. It is in consequence of a one-sided hypertrophy of this kind, that the majority of the species soon lose that bilateral symmetry which in early life prevails in this group, as well as in those previously noticed.

To a similar regional development in the middle line of the body is to be ascribed its flexure upon itself, and the approximation of the two orifices of the alimentary canal; features, both of them, very characteristic of the Molluscan type. Two leading varieties of flexure are distinguished by Mr. Huxley as the neural and hæmal modifications of the common plan.

In the first the curvature is towards the foot, owing to the expansion of the forepart of the opposite or hæmal region, accompanied by a bend of the intestine

Fig. 33. NEURAL MODIFICATION OF THE COMMON TYPE OF MOLLUSCA

into it, the concavity of which is directed downwards. This arrangement prevails in the Cuttlefishes, a class termed by naturalists *Cephalopoda* or *head-footed*, because the neural disc or foot is prolonged forwards

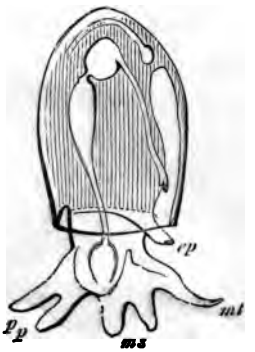

Fig. 34. CEPHALOPOD MODIFICATION OF THE COMMON TYPE OF MOLLUSCA.

pp, *ms*, *mt*, parts of the foot modified into tentacles, which are here shown directed downwards, as in creeping over a surface; *ep*, epipodium, modified into the funnel. The alimentary canal, and above it the heart, are seen in the shaded part of the figure, as in the last.

so as to involve the mouth, around which its marginal lobes form a circle of tentacles or arms, serving for progression over a hard surface, as well as for swimming and the capture of prey. In this class the shell, when present, is of one piece, but divided internally

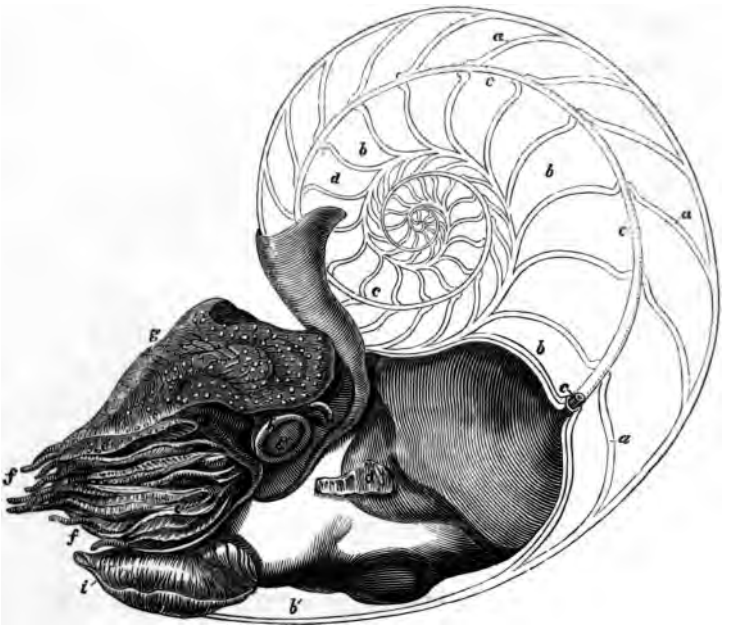

Fig. 35. THE PEARLY NAUTILUS.

Showing the spiral shell with its chambers, *b b b*; curved partitions, *a a a*; and siphon, *c c c*. The animal occupies only the last chamber, into which it is here shown drawn back; *h*, the eye; *f f*, the tentacles; *g*, another part of the disc or foot, serving probably as an organ for creeping along the ground.

into chambers, of which only the large outer one is occupied by the animal. Though coiled into a spiral by the continually increasing enlargement of the mid-hæmal region, it preserves a bilateral symmetry, as does the animal itself. Another important particular, in which the Cephalopod differs from the lower Mollusca, is the presence of a gristly brain-case in the head, which may be regarded as the rudiment of an internal skeleton. The head is well developed, and is made still more conspicuous by its pair of large eyes, and its crown of arms covered with curious sucking discs (*fig.* 36.).

In the second or hæmal modification of the Molluscan type, the region whose development produces the flexure is that lying behind the anal orifice. The curvature in this case is directed towards the dorsal aspect of the animal, and the concavity of the intestinal bend embraces the heart. The hæmal modification is characteristic of such animals as the whelk, periwinkle, and limpet, which have been termed *Gasteropoda*, or *belly-footed*, from their only organ of progression being the ventral disc mentioned already. The Gasteropod mollusc has usually a univalve shell, commonly coiled like that of the cephalopod into a spiral, but without any internal divisions, and manifesting that departure from

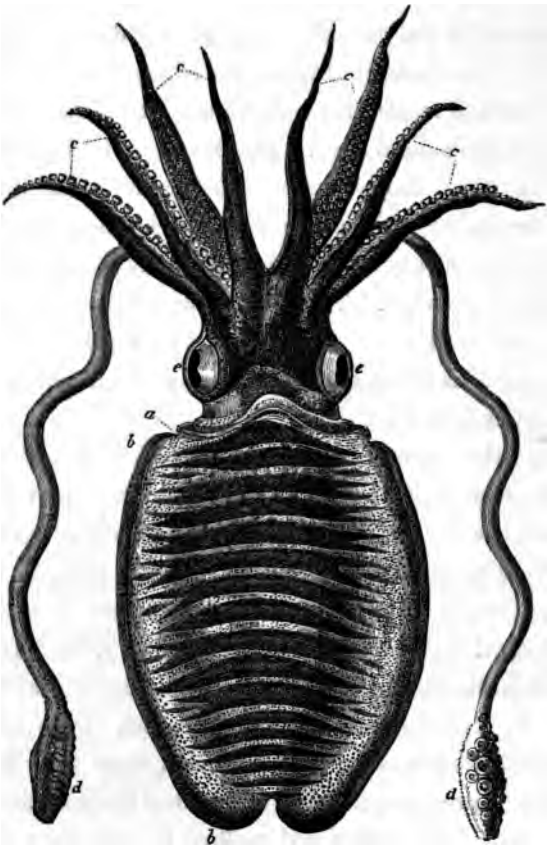

Fig. 36. COMMON CUTTLEFISH (*Sepia*),

With the neural disc and tentacles uppermost, as in swimming.

a, funnel; *b b*, body of animal; *c c c c*, eight shorter arms for locomotion; *d d*, two longer arms for prehension, both sets furnished with suckers; *e e*, eyes.

bilateral symmetry so frequently met with in this group of animals. (*Fig.* 40.)

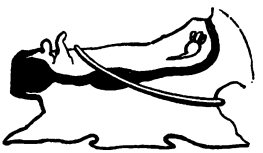

Fig. 37. HÆMAL MODIFICATION OF THE COMMON MOLLUSCAN TYPE.

Fig. 38. MODIFICATION OF THE MOLLUSCAN PLAN, IN A SHELL-BEARING GASTEROPOD (*Periwinkle*).

m, mouth; behind it the neural loop, encircling the gullet; *h*, heart, lying in the open of the intestinal bend; *p*, mantle, lining the free edge of the shell; *f*, the foot; *o*, the operculum, or lid, by which the mouth of the shell is closed, when the body is drawn back into it; *t*, tentacles of the head (*after Huxley*).

Finally, in the extensive class of bivalve shell-fish, termed by some *Acephala*, from their having no distinct head, there would seem to be both a hæmal and a neural flexure. (*Fig.* 39.) To this class are referred the oyster, mussel, cockle, and such like species.

No apology seems necessary for not going into further details in regard to the homologies of the Mollusca, as a more extended discussion would have

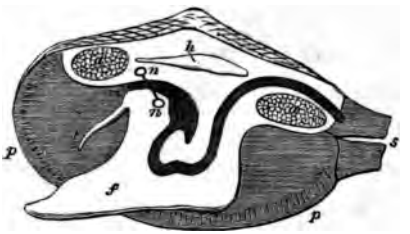

Fig. 39. HÆMO-NEURAL MODIFICATION OF THE MOLLUSCAN PLAN, CHARACTERISTIC OF BIVALVE SHELL-FISH.

m, mouth ; *n n*, neural loop ; *h*, heart ; *f*, foot ; *t*, oral tentacle ; *p p*, one half of the mantle lining a valve of the shell ; *a a*, muscles which close the shell ; *s*, respiratory tubes.

little interest for the general reader, while to those desirous of making them the subject of special study, it would prove but an indifferent substitute for the works of original writers on this branch of natural science. Mr. Huxley's treatises in particular deserve the consideration of the student, for though there may attach a certain ambiguity—as he admits himself—to some of his conclusions, he seems to have abundantly established the general principle that the modifications of the common plan,—which in Vertebrata and Articulata are dependent on the over-development or abortion of some of the parts entering

into the composition of the several segments, or by the addition or subtraction of entire segments of the skeleton—are to be ascribed in Mollusca to local expansions of certain parts of the soft body of the animal. By such outgrowths of particular regions we are to explain, not only the very general loss of symmetry, and the neural and hæmal flexures characterising the several classes, but also the origin of such appendages as the arms and funnel of the cuttle-fish, and the gill-tufts and tentacles of other Mollusca. Even the so-called external skeleton or shell—which

Fig. 40. SHELL OF MUREX,

Showing the spines at the mouth, formed on corresponding projections of the free edge of the mantle. Similar spiny fringes on other parts of the shell indicate the protrusion of such marginal lobes at former periods of growth. The terminal tubular projection is for the protection of the siphon or respiratory canal.

is certainly the most permanent, as it is to general observers the most characteristic feature of the group—is

merely the calcareous cast of such an expansion; being moulded upon the fold termed the *mantle*, whose characters it faithfully preserves even to the papillary prolongations of its margin, which are a distinguishing mark of some species.

CHAP. VI.

CONFORMATION OF THE RADIATA AND PROTOZOA.

At the head of the group of Radiata—or animals whose parts are arranged not in pairs, or on each side of an axis as in the higher divisions, but in a ray-like manner round a common centre—Cuvier places the sea-urchin, the starfish, and allied species, under the name of Echinodermata, or spiny-skinned animals, in allusion to the integument generally developing a calcareous skeleton of bars and plates, which coalesce into an elaborate network or pavement, garnished with spines, tubercles, &c.

Five is the prevailing number in this class. Not only is the circumference of the body divisible into five equal and similar segments, but even the more minute details of its organisation appear to be subject to the same law. "Every plate of the sea-urchin is built up of pentagonal particles. The skeletons of the digestive, the aquiferous, and tegumentary systems equally present the quinary arrangement, and even the hard framework of the

disc of every sucker is regulated by this mystic number." *

Naturalists are not agreed as to the parts here representing the true blood-vessels of other animals, but the homologue of the œsophageal nervous collar of the higher Invertebrate groups is clearly traceable in the ring surrounding the gullet. In this way we may determine that it is on the neural aspect that the mouth is situated, and may therefore conveniently apply the term hæmal to the opposite one, on which —as in Mollusca—the terminal orifice of the alimentary canal is commonly to be found.†

In the usual position of the body the oral or neural aspect is also ventral, and its plates are furnished with tubercles bearing movable spines, sometimes of large size, which form a sort of locomotive appendages. But the principal organs of progression are small flexible worm-like tubes, which are thrust out through holes in the calcareous shell, and being attached by sucking discs at their ends to any fixed object, serve by their subsequent retraction to draw the body in that direction. "The little suckers are extended in

* Introduction to Prof. E. Forbes's Monograph on British Echinodermata.

† These aspects are commonly termed *oral* and *apical*, or *ambulacral* and *antambulacral*.

all directions, often to such an extent that they appear only like thin semi-transparent hairs. At length one fixes, then another and another, until at last a number of them, all contracting together, drag their unwieldy owner a step forward."* The calcareous framework of the hæmal or dorsal aspect is simply tuberculated, and bears no suckers.

In some species we find appendages more comparable to the limbs of other animals, in the five greatly prolonged marginal lobes or rays of the body, as is well seen in the common star-fish. There are great varieties in the development of these rays. In some species it is carried only so far as to give the body a pentagonal outline, while in the brittle-stars the lobes appear like long tentacles attached round the edge of a central disc, and in the Gorgon's-head they are developed into arms which send off innumerable ramifications.

All the rayed species are considerably flattened, but in those of a circular outline the body is generally much more convex, and sometimes almost globular, as we see in the sea-hedgehog or urchin. In this form, the portion of the integument corresponding to that of the upper half of the star-fish, is

* Dallas, in Orr's Circle of the Sciences, Organ. Nat. vol. ii. p. 262.

contracted to a small circle at the apex, while the suckers are arranged in five bands or *ambulacra*,

Fig. 41. STARFISH (*Asterias*).

The upper tuberculated surface is shown, with some of the spines of the under surface projecting at the sides of the rays. At one of the angles between the rays, on the right side, is seen the eccentric calcareous plate, or madreporic tubercle, which indicates the existence of a bilateral symmetry.

which run nearly from pole to pole, like the meridians of a globe, and answer to the under surface of the rays of the star-fish.

If we suppose the vertical extension carried still farther, we should have the cylindrical body of the

holothuria or sea-cucumber, an animal having some affinity to the lower forms of the articulate group. An articulate or annulose character, indeed, has been ascribed to the whole class; as indications of bilateral symmetry, which have been thought inconsistent with a truly radiate structure, are certainly always discernible*, and in the embryonic condition of some of the species are often very decided. If in any sense

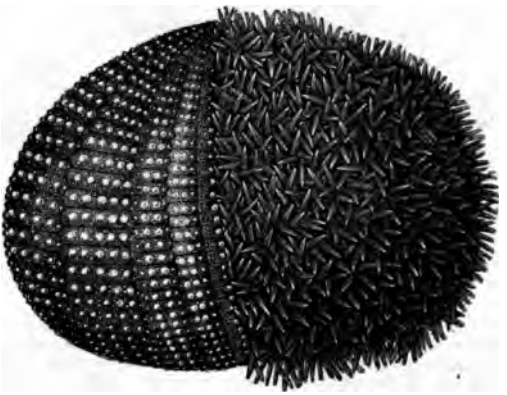

Fig. 42. SHELL OF ECHINUS, OR SEA-URCHIN.

On the right side covered with spines, on the left the spines removed.

an articulate animal, the sea-urchin must be regarded as walking on its head—like the cuttle-fish among

* In the eccentric position of the madreporic tubercle, and some parts of the digestive canal, and frequently also of the anus.

Mollusca—and the neural aspect would require to be extended along the meridional bands, or ambulacra on one side of the animal. It is so far in favour of this view that in some species there is a special surface for progression, formed by two of the ambulacra and the intervening space.

The relation between such modifications of the Echinoderman organisation as the star-fish and sea-

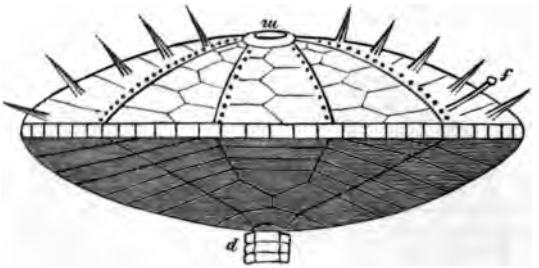

Fig. 43. PLAN OF THE EXTERNAL CRUST OR SKELETON OF ECHINODERMATA.

The hæmal or apical aspect is shaded; the neural is given only in outline, with the mouth, *m*, in the centre, and the spines and perforated bands on which are placed the sucking feet, *f*. In the pedunculated forms the animal is inverted; *p*, the point of attachment occupying the centre of the *lower* surface.

urchin, may be farther illustrated by imagining, as a common form, a flattened circular body, on the under side of which we should have the apertures for the suckers in five bands radiating from the central mouth, the whole surface being farther covered with

a spiny integument. If we suppose the perforated bands drawn out into arms all round the margin of the disc, we should have the general characters of the star-fish. But if, instead of this, we suppose the disc blown up into a ball, and at the same time the tuber-

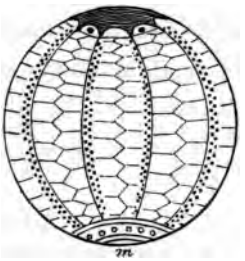

Fig. 44. MODIFICATION OF THE SKELETON IN THE URCHIN,

Showing the proper dorsal surface reduced to the small shaded circle at the top ; *m*, the mouth in the centre of the lower surface, from which the perforated bands for the protrusion of the suckers are carried up, like meridians, almost to the apex. The suckers themselves, as well as the spines, with which the whole surface is covered, are supposed to be removed (Huxley).

culated dorsal surface reduced to a small circle at the apex by the prolongation upwards of the ambulacral bands, and the general spiny investment of the neural aspect; then, as the result of our transformation, we should have an Echinus or sea-urchin.

But it is not in their general configuration only that a common plan is traceable among the Echinodermata, for the researches of Muller, Gaudry, and others show that it extends also to the disposition of

the internal organs, and to many details in the minute structure of the tegumentary skeleton.

The other species still retained by naturalists among the Radiata form the group termed by Huxley *Nematophora*, or thread-bearers, from the barbed filaments contained in their surface-cells, and possessed of virulent stinging powers sufficient to destroy the life of small animals, and even in some cases to make a most painful impression on the human skin.* This name he has since abandoned

* Agassiz, who has particularly examined these stinging organs, calls them *lasso-cells*, in allusion to the filament or microscopic thong which is coiled up in their interior. Dr. W. Burnett remarks on the wonderful complexity of these minute structures, of which he gives the following description: "There are several varieties of these cells or capsules, depending on the arrangement and structure of the lasso; sometimes this last is a simple coil; sometimes it is coiled about a staff which is erected from the base, but which is also a part of the projectile apparatus. In the first case, the lasso is much the longer, and may be fifty or seventy-five times the length of the vesicle; while in the second case it rarely exceeds the length of this last by more than sixteen or twenty times. In all cases the essential feature of these organs is the lasso or internal coil, which is of a most curious structure. In the first place it is, in general terms, only an inverted portion of the vesicle or cell itself, an internal instead of an external *cilium*, coiled up in a regular manner. When thrown out, therefore, it is wholly inverted, and its projection consists of an instantaneous turning of the whole inside out. But the lasso, delicate as it is, has still more delicate structures on its surface. These consist of barbels arranged in regular spiral

for that of Cœlenterata, previously adopted by Frey and Leuckart, to express the continuity of the digestive sac with the general cavity of the body.

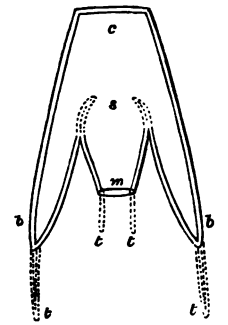

Fig. 45. CŒLENTERATE PLAN.

m, oval protuberance, sometimes a mere lip, at others prolonged, or fringed with a circle of tentacles, *t t*; *b b*, margin of bell, bearing tentacles, *t t*; *s*, internal fold, prolonged in the higher species into an imperfect stomach ; *c*, general cavity. All these reduplications consist of two layers, an outer and an inner.

Their organisation, of which this is the most prominent characteristic, embraces, from its simplicity, so few elements that we can no longer employ the terms hæmal and neural, as has been done in all the

rows, which extend to the very extremity of the lasso. At this last point they almost elude the highest and best microscopic powers. These barbels all point backwards when the lasso is extended, and serve, no doubt, as teeth to prevent it from slipping on the objects over which it is thrown."—Siebold's Comp. Anat. of the Invertebrata, by Dr. W. Burnett, p. 40. *note.* Figures of these cells are given in the "Micrographical Dictionary" of J. W. Griffith and Arth. Henfrey.

previous divisions, for blood-vessels have as little existence as an alimentary system, apart from the general cavity of the body, and the evidence in favour of a nervous system, even in the higher species, is of a questionable nature. Yet there is here discernible a plan of construction as uniformly characteristic of the group, as in any of the cases already considered. The body, according as it is erect or inverted, has the general shape of a cup or a bell, with tentacles on its free margin, and in the centre of its concavity a protuberance bearing the mouth. (*Fig.* 48.) This appendage is sometimes so prolonged as to resemble the tongue of the bell, or the stalk of an umbrella; in other cases it is little more than a circular lip. The mouth communicates with the general cavity of the body—directly in the lower forms—in the higher through the intervention of a stomach whose walls are deficient below. (*Fig.* 46.) The only representatives of blood-vessels are tubular extensions of the same general cavity.

In all varieties of sea-jellies, sea-anemones, coral animalcules, polypes, and other zoophytes, this general plan is traceable, though an endless diversity is introduced into the series, not only by special modifications of the bell, tentacles, oral protuberance, and other parts of the typical structure, but still more by the

development of compound organisms. Just as a tree is formed by the continual formation of new buds and their evolution into leaf-shoots, so, in the case of the zoophytes or plant animals, we have a continued suc-

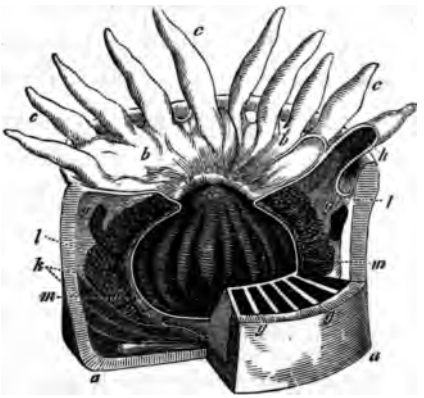

Fig. 46. DIAGRAMMATIC SECTION OF A SEA-ANEMONE (*Actinia*).

The inner or true stomach *e*, is shown, as well as the outer or peritoneal cavity *l*, with its radiating septa *g g*, and the passages *h*, into the tentacles *b c*; but not the opening at the base of the stomach, by which that sac communicates with the general cavity *a*, surface of attachment or base of the animal; *m*, ova.

cession of polyp-buds, which remain in organic union with their predecessors, and form those horny, shrub-like productions common on our own coasts, and occurring on a larger scale in the coral-reefs of the tropical seas.

Four, or some multiple of it, is the number which generally prevails in this group. "In Cyanæa, for

example, the stomach is usually subdivided by four; four œsophageal tubes are continued to their com-

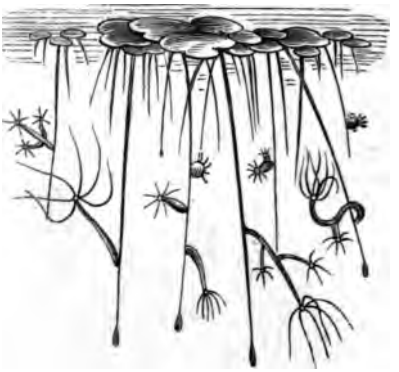

Fig. 47. A GROUP OF POLYPES (*Hydra fusca*) ATTACHED TO THE ROOTS OF DUCKWEED,

In different stages of extension and contraction, and some of them multiplying by buds.

mencement, which is in the form of a quadrate mouth, the angles being prolonged into four ten-

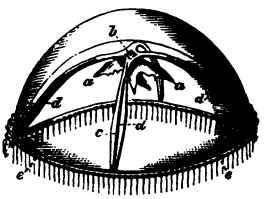

Fig. 48. THAUMANTIAS PILOSELLA (*a Naked-eyed Medusa*).

Showing the oral protuberance *a a*, in the centre of the bell, and the tentacles round its edge. The peritoneal or general cavity is here represented only by the canals *d, d*, which radiate from the stomach *b* and the marginal canal *e e*, in which they terminate; *c* one of the four coloured ovaries.

tacles. Sixteen canals radiate from the central cavities." * In all the large sea-jellies the four coloured ovaries are a conspicuous feature.

But well marked as is the typical construction both of Echinodermata and Cœlenterata, we shall find it very difficult to establish any community of organisation between them. Some resemblances certainly there are, such as that expressed by the common

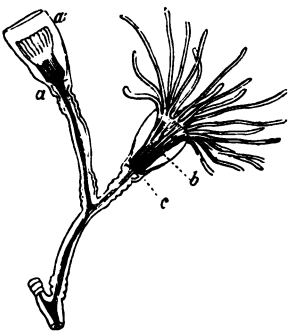

Fig. 49. A COMPOUND POLYP (*Campanularia*).

Showing the bell-shaped body *b*, with a fringe of tentacles round its free edge, which conceals the central protuberance of the mouth in its concavity; *a*, horny cell, into which the animal can be retracted — it is formed by the induration of a reflected layer of the outer wall; *c*, stalk connecting the polyp with the rest of the colony; it is hollow, and communicates with the general cavity of the animal.

name, the radiated arrangement, especially observable on the oral surface, or that which in the

* Dr. Dickie, Typical Forms, p. 276.

unattached species of both classes is ordinarily directed downwards.* There is ground, however, for thinking that undue importance may be attached to this, for it has already been shown not to prevail so exclusively among the Echinodermata as appears at first sight, and we are not without indications of the same in the higher species of the other divisions. The conspicuous coloured tubercles on each side of the mouth of the sea-anemone, and the internal membranous folds with which they are connected, are examples of this. But even were the character more absolute than it is, still, as confined to a single feature of the exterior, it cannot be of great value in connecting groups whose internal economy is so utterly diverse, and of which one is so far below the other in the scale of organisation. We find, indeed, that something of the nature of a radiated arrangement of parts recurs with varying distinctness in different

* It is to be observed, that in the attached species—as Pentacrinus in the one class, and Actinia, &c., in the other—the oral aspect is turned upwards. And we find when a species originally fixed becomes free, it actually reverses its position; of this we have examples in Comatula, and the Medusiform zooids of various polypes.

Even in the higher groups we find the attached species generally inverted. If it be thought fanciful to refer to the Mammalian embryo, suspended, face upwards, by the umbilical cord, compare at least the barnacle with its own larva form, or with other Crustaceans, and the Molluscan polype with the cuttlefish.

parts of the animal scale. Something of the kind appears in certain species of wheel animalcules, of intestinal worms, of Annelidans, and even of the lower Arachnida*—that is, in organisms whose affinities are on the whole with the Articulata. Again we meet with the same among Mollusca, in the cuttle-fishes, and the Polyzoa. The latter class in particular so much resemble the true polyps, both in their oral circlets of tentacles and in their tendency to the development of compound structures, that even since they have been referred to their right place by Milne-Edwards, they still go under the name of *Molluscan zoophytes*.† Even in Vertebrata we find more than a bilateral symmetry—the parts being repeated, in so far as the limbs are concerned, at the opposite extremities, as well as on both sides of the trunk.‡ Such *homomorphism*, or representative recurrence of certain forms, apart from any real affinity, has attracted the notice of several naturalists. An interesting illustration of this kind of resemblance

* E. g. *Stephanoceros*, *Cysticercus*, *Siphunculus*, *Ammothea*, &c.

† The homologies of this interesting class have been fully discussed by Huxley; also by Allman, in a paper in the Trans. Roy. Ir. Acad. 1852, and in a Monograph of the Freshwater Species (Ray Soc), p. 43. *et seq.* These authors differ in their views on some important points.

‡ See below, at p. 156.

between a Molluscan polyp and an Annelidan worm is given by Allman in the monograph* quoted in the note, and he alludes, in connection with it, to a similar parallelism in the vegetable kingdom, between certain species of Cactus and Euphorbia.

Elementary as is the organisation of the type last under consideration, we do not in it see the utmost simplicity of structure capable of manifesting the phenomena of animal life. In the case of the Protozoa, however—of which the Infusory animalcules are the most familiar example—we may be said to have at last attained this limit. For here we have the animal fabric reduced to a state of such extreme simplicity, that there scarce remain differences of structure sufficient to constitute a type of organisation at all. In fact, the only constant elements seem to be a roundish mass of gelatinous contractile matter—the

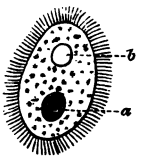

Fig. 50. PLAN OF PROTOZOA,

Showing the nucleus *a*, and a vacuole or contractile space *b*. The cilia, here represented as covering the whole surface, may be wanting over a greater or less extent, while, in some forms, the integument, in whole or part, is converted into a rigid shell.

* Op. cit. p. 57. *note.* For an independent account of this animal by its discoverer, Dr. Wright, see Ed. New Phil. Jour., Oct. 1856.

body of the animal—and a central nucleus. Just as we have already seen the internal skeleton, the vascular, and the nervous systems vanish in succession, so in the lower forms of life contained in this division the integument and the digestive cavity also disappear, and the animal is reduced to a soft, nucleated mass, nourished either by simple absorption, or by the impaction of alimentary particles into its plastic substance.

The absence of any investment of the *sarcode* or contractile matter of the body is shown by the way in which it shoots out finger-like projections in all directions, and again draws them back into the general mass. (*Fig.* 51.) By a process of the same kind the substance of the creature may grow round any object which can serve as food until it is completely enclosed within the body, when it is gradually dissolved. "The substances swallowed, if such a term be admissible, by this hungry mass of jelly, are sometimes so large that the creature itself only seems to form a gelatinous coat enclosing its prey.

In the higher species, however, a mouth, and in some cases also a digestive cavity, are met with. A tegumentary pellicle, too, exists in the majority of

* Dallas, in Orr's Circ. Sciences, Organ. Nat. ii. 205.

these animals, and is frequently clothed with *cilia*, or vibratile hairs, which serve as organs of progres-

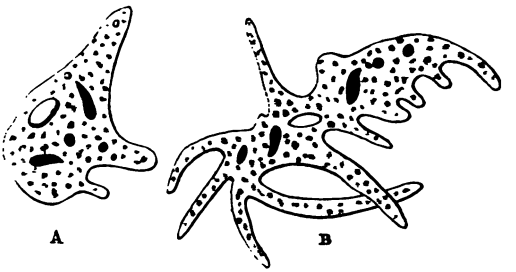

Fig. 51. A MICROSCOPIC PROTOZOON IN DIFFERENT FORMS, *A*, *B*. (*Amœba princeps* Ehr.)

Showing the extemporaneous feet (*pseudopodia*), formed by evanescent projections of the general plastic mass of the animal.

sion, while in other cases it developes a calcareous or flinty shell, often of an exquisitely beautiful pattern.

Fig. 52. A COMPOUND FORAMINIFEROUS PROTOZOON MAGNIFIED.

The shell is perforated with holes, through which the different lobes of the animal communicate, and thread-like portions (*pseudopodia*) are protruded externally.

Some Protozoa present even a sort of anticipation of a vascular system in an internal pulsatory cavity near the nucleus. (*Fig.* 50, *b*.)

Farther, though the individuals are always of minute size, for the most part invisible to the naked eye—yet by a process of continued budding, as in the polyps, compound organisms are formed of considerable dimensions and no small complexity of structure. We have instances of this in the sponges, and in the Foraminifera, which have lately been made the subject of careful research by Dr. Carpenter and Professor Williamson.*

* For figures of the compound Foraminifera, see Microgr. Dict. pl. 18, and the beautiful monograph of the British species by the last-mentioned author, just published by the Ray Society.

CHAP. VII.

MUTUAL RELATIONS OF THE LEADING TYPES OF ORGANISATION.

In the foregoing sketch of the salient features of the main divisions of the Animal Kingdom, it has been the endeavour of the writer to fix attention as exclusively as possible on the general type of organisation characteristic of each group, and to make no farther reference to particular species than as they served to illustrate the common plan; the object not being to accumulate examples of special adaptation, but to show, as was stated in the commencement of the work, that though a community of construction cannot be maintained for the Animal Kingdom as a whole, yet it is quite demonstrable in each of the great primary groups. The want of conformity between the Echinodermata and the other Radiata, only goes to show that the latter group, as generally admitted, is not a natural one, in the same sense as any of the others—as the Vertebrata for instance. It becomes so, however, by the abstraction of the Echinodermata; though what

are really the proper affinities of this class must be admitted to be at present one of the most puzzling questions in the whole range of systematic zoology.

Of such points as are already satisfactorily ascertained, in regard to the great types of animal organisation, Prof. Huxley has given an admirable summary in his introductory remarks to a recent course of lectures on natural history.

"We find," he says, "that there is in reality a strictly definable community in the arrangement of the essential organs among the members of each typical group, while this plan is different from that of any other group.

"Thus among the Vertebrata we find that of the three great systems of organs, alimentary, vascular (hæmal), nervous (neural), — the former occupies the axis of the body, while the centres of the latter are situated, one upon its dorsal, the other upon its ventral side [aspect]. The anterior part of the alimentary canal does not traverse the nervous centre, being separated from it by a partition containing a peculiar body, the *chorda dorsalis* [rudiment of the spinal column].

"The body is divided into successive segments; the limbs when developed are turned away from the neural side, so that the creature moves with its hæmal side turned downwards. There is an internal skeleton.

"In the Annulosa [Articulata] there is the same relative position of the great central organs to one another, but the neural side is that which is ordinarily turned downwards. The anterior part of the alimentary canal perforates the nervous centre, which is not separated from it by a partition containing a chorda. The body is composed of successive segments, usually provided with limbs, and the skeleton is external.

"In the Mollusca, the relation of parts in the general plan is essentially the same as in the Annulosa, but the body is not composed of successive segments, and no true articulated limbs are ever developed.

"The plan of the Cœlenterata differs from that of any of the foregoing, in the general absence of either nervous or vascular centres; and in the free communication of the alimentary canal with the general cavity of the body, which is bounded by two distinct membranes, an external, representing the 'serous' layer of the germ, and an internal, representing the 'mucous' layer.

"Finally, the last plan, that of the Protozoa, is characterised by the absence of distinct nervous vascular and alimentary centres, of any differentiation of the body into serous and mucous layers, and by the general — if not universal — existence of a so-called 'nucleus' in the interior of the body. The existence

of a peculiar organ * * * 'the contractile vesicle,' also seems to be peculiar to, though not invariable in this type."*

Mr. Huxley then proceeds to consider the bearing of embryological researches on the typical forms which, from the comparison of the adult organisation of many different species, have been assumed as characteristic of the great primary groups. He observes that "the doctrine of common plan, if it rested on anatomical grounds alone, would be by no means secure. For animals not only *are*, but *become*, and it is within the limits of logical possibility, that the adult forms, anatomically similar, should be genetically different; that they should have arrived at a similar point by different roads. Before then we can affirm that two animals are constructed upon a common plan, or that two parts are homologous, (which simply means that they are modifications of corresponding members of a common plan,) we must be able to show that these parts or these animals have passed through a corresponding series of developmental stages.

"Now, so far as I am aware, the application of the test of development to the actual modifications of the five common plans, as I have above defined them,

* Huxley's Lectures on General Natural History, in Med. Times and Gazette, May 3, 1856.

has invariably tended to strengthen the grounds upon which they have been established; and to clear away all anomalies and apparently transitional forms.

"As a rule — the apparent exceptions to which gradually disappear under careful investigation — every Vertebrate, every Annulose, every Molluscous, and every Cœlenterate germ, passes through the condition of what is termed yolk-division, or something corresponding to it, and becomes a blastodermic vesicle or disc, composed of two more or less anatomically distinct layers, one of which gives rise to the tegumentary organs, the skeleton, and the so-called organs of animal life: while from the other the chief alimentary organs are developed. On the other hand, in the Protozoa, nothing corresponding to this yolk-division and subsequent production of a double blastodermic layer or vesicle, is known to occur. There is therefore one condition, that of the 'germ,' a particle of 'viable matter,'* with or without a central endoplast [nucleus], which is common to all animals, and in this sense alone can any unity of organisation be predicated of them. Of all except the Protozoa, however, we may assert a farther unity of organisation, viz. that they pass through yolk-division or something

* Matter capable of life.

corresponding to it, and become blastodermic discs or vesicles. Beyond this point each animal seems to branch off into the form peculiar to the common plan of the division to which it belongs; and so gradually becoming more and more specialised, it assumes the plan of the family, the genus, and the species; in its adult condition only taking on its final and individual peculiarities." *

A subject so important as the embryological verification of the doctrines of homology seems to warrant the introduction of a few additional remarks, with the view of indicating, to such as are not conversant with physiology, how the progress of organisation eventually results in the recognised types of the primary groups. In all animals it would seem that the first germ of the future being is a microscopic capsule or cell, containing within it another smaller body or nucleus, also of a vesicular nature. These structures are termed the *ovum* and the *germinal vesicle.* In all but the Protozoa, the inner cell disappears on fertilisation, and the contents of the ovum, or part of them, undergo that yolk-division or segmentation just referred to, becoming cleft, first into two distinct masses, then into four, and so on, by a course of successive halving, till they present

* Huxley, Op. cit.

at last that appearance of an agglomeration of minute spherules, which has suggested the name of "mulberry body."* Subsequently the granules on the exterior cohere to form an enveloping layer, which goes under the name of *blastoderma*, or formative membrane, as being the nidus of all future development, while the contents are known as the yolk or vitellary mass.

Here, in the case of the Cœlenterata, the organising process may be said to stop, there being reason to believe that "the cells of the interior liquify, so as to leave a cavity, which becomes the stomach, whilst the cells of the exterior remain to form the walls of that cavity, and absorb its contents; that a thinning away takes place in a certain spot of this wall so as to form the mouth; and that the tentacula are gradually developed around the mouth, making their first appearance as little knobs, and then progressively elongating themselves, until they have attained their normal dimensions."† It is to the

* Allan Thomson shows, in his article on the Ovum, in the last volume of the Cyclopædia of Anatomy and Physiology, that the true homologue of the Mammalian ovum undergoes complete segmentation in all animals; the non-segmented portion really consisting of adventitious matter, part of the general contents of the ovisac.

† Carpenter, Princ. Phys. Gen. and Comp. p. 919.

various projections and reduplications of one or both of the layers of which the enveloping membrane is composed, that the diversity in the configuration of the species of this group appears to be mainly due.

In the three higher divisions, only part of the blastodermic membrane enters into the permanent organisation, which in their case is subsequently induced upon it, and generally speaking we have structures formed during embryonic life, which are only provisional, being afterwards thrown away. We have already referred to instances of this, as the shells of Mollusca, which are afterwards naked, the eyes and swimming-feet of the lerneans and barnacles among Crustacea, and the tail of the tadpole; and to these we may add the yolk-sac of the Mammalia.

Finally, the segmented animals of the two higher groups, which present so striking a parallelism in their mature organisation, have also a closer conformity than any others in their embryonic development, though their fundamental diversities are at the same time clearly indicated. In both the shell of the body is formed by a peculiar folding up of a thickened portion of the blastodermic membrane. In Articulata its two edges curve upwards, and, by meeting on the neural aspect, form the tunnel-like

wall which encloses the viscera. In Vertebrata again there are two pairs of laminæ, proceeding from a central axis; for while the dorsal folds turn upwards to form the neural canal, those on the ventral aspect curve downwards, towards the centre of the yolk, so as to enclose the larger hæmal cavity, their ultimate point of junction being indicated by the navel. Hence "the Annulose, like the Vertebrate animal, is developed with its nervous axis turned away from, and its hæmal axis applied against, the vitellary mass. But in the course of development the mouth of the Vertebrate opens through the surface applied against the vitellary mass, whilst that of the Annulose animal passes through the aspect turned away from it. The Vertebrate mouth is hæmal, the Annulose mouth neural." *

Without going into farther details — which could not be made intelligible without figures and a lengthened description — it may be stated in general that the subsequent course of embryonic development in Vertebrata presents first peculiarities which clearly mark off the fish from the air-breathing animal, and then others distinguishing the oviparous classes from the Mammalia.

* Goodsir, in Ed. New Phil. Jour., Jan. 1857, p. 120.

The relations of Vertebrata, Articulata, and Mollusca, thus indicated on embryological, as well as on anatomical grounds, are concisely stated by Agassiz, as follows:—

"The type of Vertebrata, having two cavities, one above the other, the former destined to receive the nervous system, and the latter, which is of a larger size, for the intestines, is represented by a double crescent united at the centre, and closing above as well as below. The type of Articulata, having but one cavity, growing from below upwards, and the nervous system, forming a series of ganglions, placed below the intestine, [that is on the aspect opposite to the dorsal vessel,] * is represented by a single crescent, with the horns directed upwards. The type of Mollusca having also but one cavity, the nervous system being a single ring round the œsophagus, with ganglions above and below, from which threads go off to all parts, is represented by a single crescent, with the horns turned down." †

* There is an inadvertency in this description; for, in referring to the nervous cord as *below* the intestine, the animal is considered as in its natural adult posture; while, in speaking of its *growing from below upwards*, the embryo is supposed to be lying on the yolk upon its back, *i. e.* with its ventral aspect uppermost, which is its real position in the egg.

† Agassiz and Gould, Outlines of Physiology, p. 337.

Of the increasing complexity of organisation, as we rise from the Cœlenterate to the Vertebrate type, we have an illustration in the multiplication of the internal cavities of the body. In most of the Protozoa, as we have seen, there is no cavity whatever, though rudiments of one appear in the higher species. In the Cœlenterata a general cavity always exists, and in the higher forms, there is a second or interior one, to which the first stands in the same relation that the abdomen of a vertebrated animal does to the stomach. Throughout the group, however, the stomach and visceral * space freely communicate and really form but one cavity. In Mollusca and Articulata again, not only is the alimentary canal shut off by distinct and entire walls from the visceral cavity, but a portion of the latter is partially separated from the rest to serve as a vascular or blood-system. Still, in the lower species, the centre of this system — the so-called heart — is merely a diverticulum of the general visceral cavity, and the blood flows backwards through the residuary portion of it, on issuing from the anterior extremity of the heart. Indeed it does not appear that in any of these animals the two systems are entirely distinct, part of the circuit of

* Huxley's term, "perivisceral," is perhaps preferable.

the blood being always through sinuses or unwalled spaces, which are really parts of the common visceral cavity.

In Vertebrata, however, we have always three distinct internal cavities, between which there exists no manner of communication whatever.

1. That for the circulation of the blood, which may be termed the cardiac cavity, because the heart forms its centre, while in its terminal prolongations it is subdivided into the capillary vessels which are the passages of communication between the arteries and veins.

2. The alimentary cavity or canal, with the stomach for its centre.

3. The general visceral cavity, which in the higher species is again subdivided into those separate and distinct serous cavities which enclose the lungs, heart, bowels and other viscera.

The other passages which exist in Invertebrate animals, and go under the names of the water-vascular system, tracheæ, &c., do not appear to belong to this series, being perhaps rather—like the cavity of the mantle in Mollusca—of the nature of diverticula from the integument, as the lung is in Vertebrata from the alimentary canal.

Farther, although in this and in many other par-

ticulars a gradation of complexity may be shown in the primary groups, and even in the subordinate divisions of each, yet it is to be observed that nothing like a continuous line exists in nature, along which we may arrange the species in the order of their perfection of organisation, for the forms included in the same division, though constructed on a common plan, often differ very widely in the completeness of their development.

CHAP. VIII.

THE LAW OF TYPICAL FORM AND MANIFESTATIONS OF DESIGN COEXTENSIVE WITH ORGANIC NATURE.

Cursory as our survey of animal forms has necessarily been, so much we can hardly fail to gather from it, that there is more in nature than the mere adaptation of means to ends, though this seems to be all that engages the attention of some of its investigators. Of such adaptations undoubtedly we have many and striking illustrations, but beyond it, we have also intimations of such a unity of plan on which the whole is constructed, as suggests the notion of some preëxisting idea, as it were, in the mind of the Creator, of which we trace the reflection in these works of His hand.

In each division of animals we can point out a very definite type, according to which the several species are constructed — a type, the essentials of which are never violated, even when it seems in a manner incompatible with the habits of particular animals — the necessary conformity being obtained in such cases, not by a departure from the type, but by a compara-

tively slight modification of some parts of the organisation, and that in a way quite consistent with its general character. Obviously the organic creation is constructed upon a great systematic plan: it is not to be compared to an overgrown village, in which the houses — commodious and well-constructed as they may be, each in itself — are scattered about without any order, every man having built as was good in his own eyes; it answers rather to our notion of a well-planned town, with the houses in regular streets, in each of which a certain uniformity prevails, while the streets themselves are arranged in that particular order, which to the founder of the city seemed the most appropriate.

In the art of architecture indeed — even as applied to individual buildings — one might trace many parallels to the typical forms existing in nature. For just as we distinguish various styles of *Masonic* Architecture, Egyptian, Greek, Gothic, &c., so in the construction of animals, we have what we may term different styles of *Organic* Architecture — Vertebrate, Articulate, Molluscan, and so forth. And — to continue the parallel — just as the Greek style appears in several modified forms, Doric, Ionic, Corinthian, &c.; and the Gothic in such as Norman, pointed and perpendicular; so we have the Annelidan, Insect,

Crustacean and other modifications of the Articulate type, and in the case of the Vertebrate, those characteristic of the four classes contained in that division of the Animal Kingdom. In both cases, too, we find that any particular style may be employed in constructions for very different purposes, without losing its own proper character. Thus we may have churches and halls, castles and private houses, in any of these styles of architecture, somewhat as we have seen the Mammalian type adapted to the flying bat, and to the fish-like whale, as well as to ordinary land animals.

There must indeed have arisen in the human mind a certain consciousness of plan in nature, as soon as those points of similarity in form were perceived which lie at the foundation of the most elementary classification — such as that into fish, and fowl, and creeping thing, and beast of the earth. But the resemblances which form the basis of the popular divisions of animals are of too superficial a kind to illustrate clearly the fundamental principles of their construction; we cannot therefore wonder that the attention of the first students of nature should rather be drawn to those striking manifestations of design, by which every creature bears its own independent testimony to the wisdom and goodness of its

Creator. To these we meet with many forcible allusions both in Holy Scripture and in other writings of antiquity, while in recent times they have been expanded with almost a tediousness of amplification in various treatises on Natural Theology.

The unity of plan on which animals are organised seems on the other hand not to have attracted any attention, and certainly did not receive any formal exposition, till the time of Oken*; while it is only within the last few years that the subject has been fully systematised — a result which we owe mainly to the laborious investigations of Professor Owen in the department of Vertebrated animals, and to those of Huxley, Dana, and Darwin in the lower divisions. Till recently naturalists, even of the first repute, seem quite to have ignored all such researches, even while devoting great attention to the harmony subsisting between the organisation of animals, and their peculiar modes of life. It is well known with what success the great Cuvier applied the results of his investigations in this direction to the restoration of entire fossil animals from a few fragments of bones, and how fully his theoretical reconstructions were, in some remarkable cases, borne out by the subsequent

* Oken's first work on the subject was published in 1807.

discovery of other portions of the skeleton; yet this author, so eminent among naturalists, and so cognisant of harmony between the different organs of the same animal, actually repudiated all inquiries into that higher harmony which subordinates animals in general to a common type of structure.*

That the philosophy of organisation, however, should be a science of late development is — as we have seen—not in itself surprising, for the recognition of uniform types in the vast diversity of animal forms required, in the first instance, an amount of acquaintance with species which could only result from the long-continued prosecution of natural history, and in the next, the energies of a mind specially gifted with the faculty of generalisation. For the essential uniformity of plan on which the primary groups of animals are constructed is obscured, not only by the great variety of trivial or accidental diversities, but also by the higher species — which first attracted the attention of naturalists — having their typical organisation more masked in this way than those lower in the scale. For the purpose of enabling

* The writer's attention has been called to the fact, that there is evidence to show that Cuvier latterly was disposed to take a more favourable view of such researches. See an anecdote bearing on this, in Coote's Homologies of the Human Skeleton, p. 86.

certain functions to be performed in a more energetic manner, their special organs are concentrated in particular regions, in such a way as to lead to corresponding deviations from the uniform disposition of the skeleton, which have been pointed out in the foregoing pages. To such an extent is this carried, that it may be doubted if the true principles of organisation would ever have been discovered, but for the great attention paid of late years to those lower forms of life, which are less encumbered by such adventitious modifications.

Late as may be its discovery, the law of typical conformation will not yield in importance, as a fundamental principle in Zoology, to that of the circulation of the blood in Physiology, or that of the revolution of the planets round the sun in Astronomical science, for it gives the character of an inductive science to one which was previously only descriptive, and it admits of being applied to the elucidation of phenomena before — beyond all others — incapable of explanation: those of the production of monstrous forms.

Yet there are still some who are slow to admit the existence of any such law, and think all the points of animal organisation explicable on principles of mere adaptation. It may not, therefore, be out of place to

adduce a few illustrations of their inadequacy to account for the peculiarities observed.

And indeed we need not go far to look for such, for in the very exact symmetry of our own bodies and those of animals generally, we meet with an instance of an arrangement of parts, to which we can rarely assign any obvious end of direct utility. The farther we trace back the course of development, the more marked is this symmetry, and the more universal. It is therefore evidently the rule, the departures from it being due to the subsequent disproportionate development of various organs. These changes we can occasionally account for on principles of adaptation, as, for instance, the greater size of that one of the anterior pair of pinching claws, with which the hermit-crab closes the mouth of its borrowed shell. But we cannot show that the symmetry itself is subservient to the well-being of the animal in any constant or general way; though in special cases of course it may — thus in birds and insects it probably makes the balance more perfect for flight; and it has been observed that in these, of all animals, this arrangement is most perfectly carried out. Yet the singular fact of the non-development of the right ovary in birds shows that we must not even

here lay too much stress on the symmetry of their other organs.

Equally inexplicable, on grounds of mere adaptation, is the constancy in the number of joints in the necks of the higher animals. In all Mammalia — with scarcely an exception — we find seven cervical vertebræ, no more occurring in the swan-necked giraffe than in the whale, which would be popularly said to have no neck at all.*

In the varied mechanism of flight we have another illustration of the same principle. This of all the faculties of animal life is perhaps the one which — but for our familiarity with it — would make the greatest impression upon us. That a gross material body should be capable of soaring at will into the impalpable air, has indeed, from the very first, excited in reflecting minds sentiments of wonder, not unmixed with envious longings to appropriate to ourselves what appeared the one great endowment in which we are surpassed by the lower animals. But in this respect human ingenuity has met with but very partial success. Though by taking advantage of

* The only exceptions appear to be the occurrence of eight or nine vertebræ in the neck of the three-toed sloth, and six in that of the manatee.

the buoyancy of certain gases, man may float himself up in a balloon, yet in so far as his movements in the air can be turned to any practical use, or are at all of the nature of proper flight, he has advanced no nearer his object after the lapse of centuries than in his first essays.

Yet in the lower animals we find not one only, but many varieties of mechanism, all efficient instruments of this superhuman art, all operating on the same general principle of the reaction of the air, and, what is more, all modifications of normal appendages, strictly conformable to the type of the species.

In two of the primary groups we have classes adapted for flight by their general conformation, birds among Vertebrata, and insects among Articulata. In the latter it would appear, at first, as if new organs were added for the performance of the function, in the wings attached to the upper aspect of the thorax, but a reference to the class of Annelida serves to show that in the completeness of the Articulate type, and without any special reference to the power of flight, we must reckon superior as well as inferior appendages, in connection with each segment of the skeleton. In insects these dorsal laminæ no longer serve for respiration, as in the lower class; but as they preserve the same relation to the vascular axis,

Oken's name of *aerial gills* is defensible enough in a homological point of view.

It is very different with the winged Vertebrata. In this group the paired limbs, which alone can maintain the proper balance of flight, are, we know, restricted to four; and we find no departure from the typical arrangement in the case of the aerial species. The power of flight is not conferred by adding on wings to the back like those of an insect, so as to leave the fore and hind legs free for progression on the earth, but the anterior pair is set aside for the performance of the special function.

In birds the requisite power in the air is given by the stroke of the vanes of quill-feathers, supported by bones answering to those of the arm, the hand and finger bones being rudimentary. But birds are not the only flying vertebrates, though they are so in a peculiar sense, and possess the faculty in the highest degree of perfection, their whole conformation being adapted to the function, and the construction of their wings possessing special advantages for the purpose. In all the other classes we can point to species which have a limited power of the same nature.

Thus we have the flying-fish, which, though probably dependent, like others of its kind, on the

stroke of its tail against the water for its first projection into the air, can to a certain extent support itself in that element by its immense fore-fins. Here, therefore, as in the bird, the power of flight, such as it is, depends on the fore-limbs; but the moving surface is different, for the arm bones are rudimentary in the fish, and feathers are unknown as tegumentary appendages. Their place is supplied by a fold of skin stretched over the fin-rays, which represent the finger bones of the higher Vertebrata, elements, as we have seen, but little developed in the bird. The hand, instead of being lost among the feathers, as in the latter, forms in the fish the whole free extremity, and is directly attached to the body of the animal.*

Among reptiles, an extinct species, the Pterodactyle, had also the power of flight. In this animal the fold of skin seems to have been stretched over one finger only, which was immensely elongated in proportion to the rest.

* As in the flying-fish the pectoral fins are expanded into a sort of wings, so do the fore-limbs of some diving birds assume, in a degree, the character of fins. This is especially remarkable in the penguin, whose rudimentary wings, covered by minute scale-like feathers, are quite unfitted for flight, though serviceable in propelling the animal through the water.

Among Mammalia, we have already had under consideration the case of the bat, and observed how strictly the proper type of structure is carried out under conditions widely different from those affecting the rest of the class. As in the cases just cited, the anterior extremities are here also the organs of flight; yet it is not effected, as in birds, by the impulse of wings fringed with feathers; the fore-limbs do not exchange their character of legs for that of pinions, the animal retains all the features of a mammalian, down even to its hairy coat, and the requisite power in the air is given by a trivial modification of its proper type, somewhat similar to those already noticed, — the extension of a fold of skin over the bones of the hand and fingers, which are all drawn out to an extraordinary length.

In all the cases now mentioned there is a power of proper flight — however variable in degree — a power of propelling the body through the air; and we have seen that universally in Vertebrata this is effected by the fore-limb — a part which is generally constructed on the general model of the arm and hand — although there is a great diversity in the part which directly acts on the air, and in the corresponding modifications which the whole limb undergoes.

"But," as Dr. Carpenter remarks, "a very different

structure prevails among those imperfect wings which serve rather to *support* the animals which possess them in their movements through the air, than to *propel* them in that medium. Thus in the flying squirrels, flying lemurs, and phalangers or flying opossums, there is an extension of the skin between the fore and hind legs, which, by acting as a parachute, enables these animals to descend with safety from considerable heights." In the little reptile, on the other hand, dignified with the name of the flying dragon, "the wings are affixed to the sides of the back, being supported by prolongations of the ribs, and are quite independent of the extremities." * Still even here there is no violation of the vertebrate type, for the stays of the dragon's wings are but modifications of ribs, which are constituents of the vertebral segments of the trunk throughout the whole group.

The wing of the bat, above referred to, is only one case among many — though an extreme one — illustrative of the fact that the limbs of all Mammalia have the same general structure, however much they may differ in their configuration and proportions to fit them for such purposes as diving and swimming, burrowing and running, climbing and flying, according

* Carpenter's Principles of Physiology, General and Comparative, p. 561.

to the habits of the species. For these, as has been before observed, have a very wide range, so that we may say of animals of this class — as Owen does of Vertebrata in general — that they "can move swiftly both beneath and upon the surface of the water: they can course over the dry land and traverse the substance of the earth: they can rise above that surface and soar in the lofty regions of aerial space." * And this though their organs of progression are all essentially of one make.

How different, as the same author remarks, from the course followed in human contrivances in which the accomplishment of a special end is the one object in view. Man, indeed — as if emulous of the natural powers of the lower animals — has by his ingenuity conceived, and by his skill and perseverance has put in practice, various devices to obtain corresponding results. "To break his ocean-bounds the islander fabricates his craft, and glides over the water by means of the oar, the sail, or the paddle-wheel. To quit the dull earth man inflates the balloon, and soars aloft, and, perhaps, endeavours to steer or guide his course by the action of broad expanded sheets, like wings. With the arched shield, and the spade or

* Owen on the Nature of Limbs, p. 5.

pick, he bores the tunnel: and his modes of accelerating his speed in moving over the surface of the ground are many and various. But by whatever means or instruments man aids, or supersedes, his natural locomotive organs, such instruments are adapted expressly and immediately to the end proposed. He does not fetter himself by the trammels of any common type of locomotive instrument, and increase his pains by having to adjust the parts, and compensate their proportions so as best to perform the end required without deviating from the pattern previously laid down for all. There is no community of plan or structure between the boat and the balloon, between Stephenson's engine and Brunel's tunneling machinery; a very remote analogy, if any, can be traced between the instruments devised by man to travel in the air and on the sea, through the earth or along its surface."* But in the organic machinery we find always a close conformity to a common type. The paddle of the aquatic whale, the wing by which the bat flutters in the air, and the trowel-shaped paw, by which the mole burrows so expertly through the soil, are all modifications of the fore-limb of the land animal, the whole being formed essentially on the same model as our own arm and hand.

* Owen on the Nature of Limbs, p. 9.

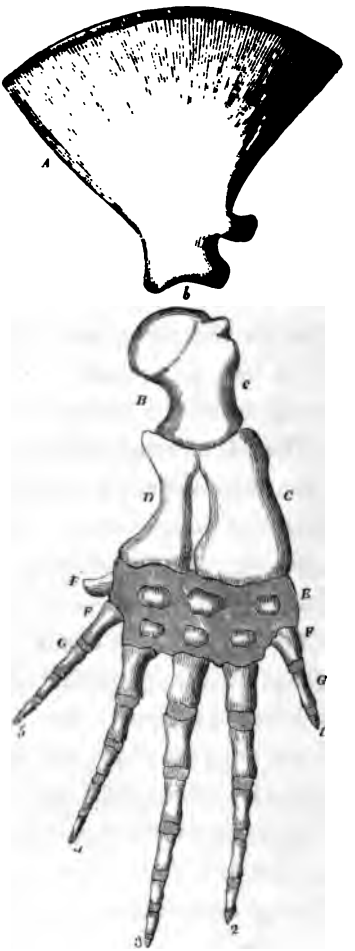

Fig. 53. BONES OF THE PADDLE OR FIN (FORE-LIMB) OF A WHALE.

A, shoulder bone ; B, arm bone ; C D, bones of the fore arm ; E F, bones of the wrist and hand ; G, 1, 2, 3, 4, 5, bones of the corresponding fingers.

Another point, noticed by Professor Owen, is the constancy with which the number five is indicated in the digits of all the higher Vertebrata. In the class

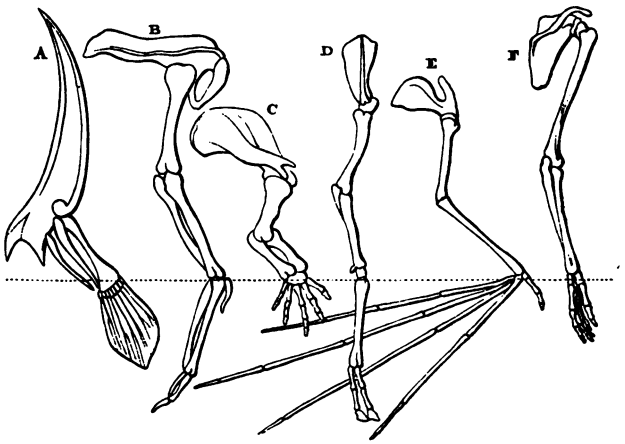

Fig. 54. BONES OF THE FORE-LIMBS IN VERTEBRATA.

A, fish; B, bird; C, dolphin; D, deer; E, bat; F, man. (*Carpenter.*) The parts above the dotted line answer to the bones of the shoulder and arm; those below, to the bones of the hand and fingers.

of fishes, indeed, in which they have only the rudimentary form of rays, their number is indefinite, varying from the single jointed filament, that constitutes the limb of the lepidosiren, to the large pectoral fin of the skate, in which there may be as many as fifty rays. But in all cases in which they assume the character of fingers and toes, we have

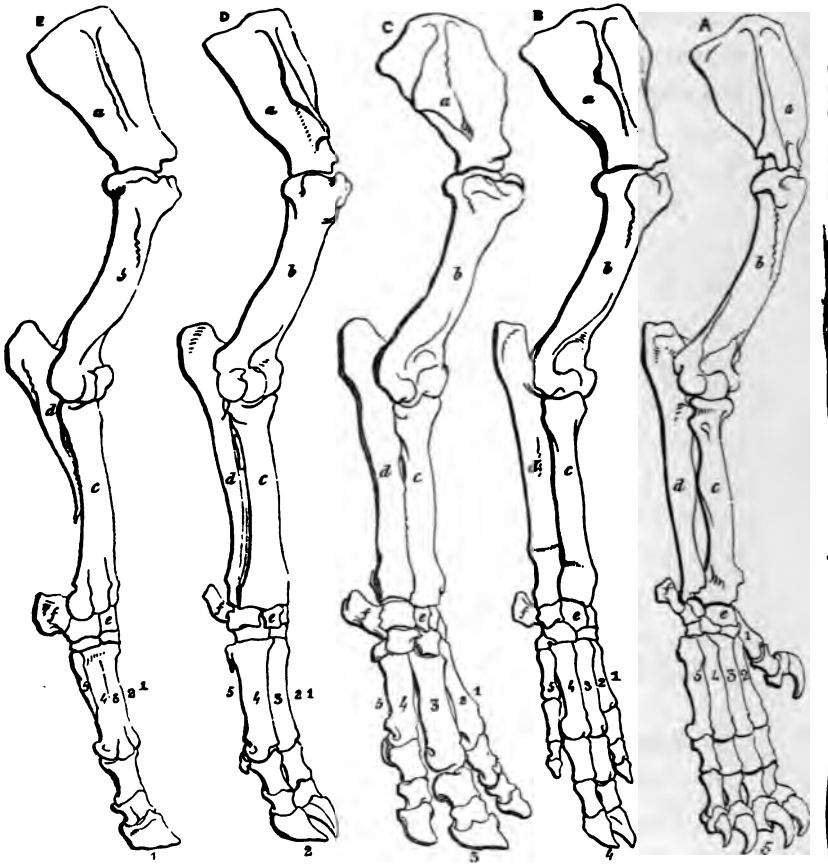

Fig. 55. BONES OF THE FORE-LIMBS OF VARIOUS MAMMALIA,

Showing a gradual elimination of the digits.

A, lion ; B, boar ; C, rhinoceros ; D, ox ; E, horse ; *a*, shoulder bone : *b*, arm bone ; *c d* bones of fore arm ; *e f*, bones of wrist ; 1, 2, 3, 4, 5, bones of the corresponding digits.

clear indications of five being the typical number. This they never exceed, and when they fall short of it, there still subsists a relation among the remaining bones, enabling us "to determine the precise digits that are lost and retained; to point out, for example, the finger in the hand of man that answers to the forefoot of the horse*, and the toe that corresponds to its hindfoot; nay, the very nail in the hand or foot which becomes, by excess of development, the great hoof of the horse."† This he determines to be the middle digit, the representative of that finger which even in the human hand shows a slight superiority in length, vindicating as it were its position as "the most constant of all in the vertebrate series, and most entitled to be viewed as the persistent representative of the terminal segments of the primitive ray of the lepidosiren." In the ox, again, the bones which support the cloven hoof answer to the middle and ring fingers.

From among the animals furnished with hoofs,

* The author of the diagram (Mr. Maclise) adopts a different view of the homology of the single bone of the horse's foot from that of Professor Owen, referred to in the text; he regards it — as will be seen by the small figures attached — as formed by the coalescence of the two bones of the ox's foot, which correspond to the third and fourth fingers of the human hand.

† Nature of Limbs, p. 30.

a regular series may be formed, as Owen and Carpenter show, in which there is a gradual suppression of the digits, till of the original five only one is left in a fully developed state. Thus in the hoof-like foot of the elephant we find the full number; in the hippopotamus, the first — or that which answers to the thumb — is wanting, as in all the following, the remaining four having each its separate hoof; in the hog there are also four, but it is only on the two middle ones, which are longer than the others, that the body rests; in the rhinoceros and tapir, the fifth, or outer digit — corresponding to the little finger — is also deficient, so that the number of toes is reduced to three: in sheep, oxen, and other ruminating animals, the third and fourth digits are enormously developed, and rudiments only of the second and fifth are present; while in the horse the third or middle digit alone is fully developed and furnished with a hoof, the others being represented only by rudiments of the second and fourth, forming what are known as the splint bones. This progressive reduction in the number of digits, and the increased development of some of those which remain, is represented by Dr. Carpenter in such a table as the following, embracing others besides hoofed animals. In it the figures of a medium size,

1, 2, 3, 4, 5, indicate the presence of their respective digits in a condition of nearly equal development, as in the human hand, while those of a smaller or larger size express a rudimentary condition or one of excessive development, as the case may be.*

Animals.	Thumb.	Fore-finger.	Mid-finger.	Fourth finger.	Little finger.
Man, Elephant -	1	2	3	4	5
Spider-Monkey -	1	2	3	4	5
Hippopotamus, Pig	-	2	3	4	5
Bandicoot - -	-	2	3	4	5
Ox, Sheep, Deer -	-	2	3	4	5
Rhinoceros - -	-	2	3	4	-
Horse, Ass - -	-	2	3	4	-

The first digit thus appears to be the least constant in the Mammalian series, and it is farther characterised by a smaller number of joints than any of the others. The next in order of inconstancy is the fifth; and it is interesting to observe that these, which are the two extremes, have even in the human hand the greatest speciality of character; while the three that are intermediate are more conformably and equally developed.

What has been here said of the hand applies also

* Carpenter's Principles of Physiology, General and Comparative, p. 527.

to the foot; for, as Owen goes on to observe in the work before quoted*, the fore-limbs of an animal are even more closely represented in its own hind extremities, than in the corresponding limbs of other species. This indeed, though as real, is not so obvious a feature in man as in most other animals. Yet it may be observed that it holds in the very point in which our species is most exceptional. In both extremities the most important element is the first digit, that one which, as we have seen in the rest of the class, is the least constant and important of the number. It is mainly the thumb which makes the human hand what it is; while the corresponding member of the foot, the "great toe," is a feature even more peculiarly characteristic of man; "for the monkey has a kind of thumb on the hand, but no brute mammal presents that development of the great toe on which the erect posture and gait of man mainly depend." Yet while in the hand both the extreme digits fall short of the rest, in the foot only one is of diminutive size, the other, the "great toe," being of larger dimensions than any of the number. But still, though this toe "is the longest as well as the largest, it resembles the thumb in its

* Owen on the Nature of Limbs, p. 38.

characteristic inferior number of joints*, whilst the fifth, or little toe, still retains, with its diminished proportions, its full complement of pieces."

There subsist, therefore, even in man, notwithstanding the marked difference of external configuration, an essential sameness in the construction of the hand and foot, which cannot be overlooked, and which extends in a degree to the whole of the corresponding members of the body. "The most superficial comparison of the limbs of our own species must impress the observer with the resemblance between the arm and the leg in their general form and character, notwithstanding the marked contrast of their powers and offices, which characterises the human species. Everyone may see that the thigh answers to the arm proper, the leg to the fore-arm, the ankle to the wrist, the five-toed foot to the five-fingered hand, in which also the thick thumb may be recognised as answering to the great toe, and the little finger to the little toe, and so of the rest." † The

* "Whether the *hallux* [great toe] be the shortest of the five or the longest, it has always the same number of phalanges [2] whenever it is present, provided it supports a nail, a hoof, or a claw in the Mammalian series." — *Nature of Limbs*, 37.

† Owen on the Nature of Limbs, p. 16. The other quotations are from the same source, with slight verbal alterations.

correspondence becomes more apparent on anatomical examination. To consider only the skeleton of the limbs, we find that the broad and flat shoulder-bone, the single bone of the arm, the pair which constitute the fore-arm, the cluster of ossicles which form the wrist, and the five bones of the hand, each with its appropriate digit, have their respective representations in the bones of the haunch, the thigh, the shin, the ankle, and the foot; the agreement extending to a variety of details which only the professional anatomist can well appreciate.

A similar correspondence in essential structure obtains in all Vertebrata, in which four limbs are present; while in many we meet with additional points of conformity, which afford a key to doubtful relations in our own species. Thus the symmetry of the two sides of the body is in some degree repeated at the opposite extremities of the trunk.

As yet another point, which mere adaptation fails to explain, may be instanced the difference in the movement of the jaws of Vertebrata and the mandibles of Articulata; the former being always vertical, the latter horizontal. Yet this diversity is but the natural result of the relation in which they stand to their respective skeletons. For the upper and lower jaws, being the hæmal arches of successive vertebræ,

one must overhang the other, as much as the first pair of ribs overhangs the second; but the mandibles of Articulata are really head-limbs, and hence opposed laterally in pairs, like the limbs attached to other regions of the body.

Still more remarkable are those cases in which organs are present though in too rudimentary a state to fulfil any function. As instances of this may be mentioned the eyes of the mole, which have no optic nerves, and those of the proteus, which are buried under the skin *; the rudimentary tail of the human skeleton; the germs of teeth in certain species of whale which never come to maturity, the animal being furnished instead with lamina of whalebone; and universally in Mammalia the nipples of male animals, always occupying the same position as those of the female.

If it should seem strange for organs thus to be provided, of no apparent use in themselves, simply that the typical conformation may be more fully represented, what shall we say to other cases in which the type is carried out, as it were, even at the positive inconvenience of the animal? For instance, in the case of the elephant, it would seem as if its

* Also the eye spots on the heads of some blind insects.

position in the scale of animal existence were actually the cause of entailing upon it a ponderous burden of bone and muscle, which it might have been spared, had not the general plan of vertebrate organisation interfered with its skeleton being formed of silex or flinty matter, like that of some of the Protozoa.

As a farther illustration we may take the case of the whale. This animal is equally an inhabitant of the wide ocean with the true fishes, but it is not, like them, furnished with gills, which would enable it to use the surrounding water as the medium of respiration. Simply, as it would seem, because it is a Mammalian, it is debarred from this convenience, and must needs respire as other Mammalians do, by lungs — an alternative which of course entails upon it the necessity of coming to the surface for air. To adapt it to the life of a fish, the Mammalian type is indeed somewhat modified, even as regards the internal organs. In connection with the arteries are various diverticula in which a quantity of oxygenated blood may be stored up, sufficient, by gradually mixing with the rest of the fluid, to carry on the vital processes during a long period of submersion; whilst the returning vessels are furnished with similar receptacles, in which the venous blood accumulates, till by the ascent of the animal to the surface it can

be again aerated in the lungs. But the modification, it will be seen, is of a comparatively trivial kind, and not such as to interfere at all with the general plan of organisation. Of course it is not meant that the substitution of gills for lungs would be of any advantage to the whale, or even that it could possibly exist, with its present organisation, under such an arrangement; as the aeration of the blood which suffices for the fish, would be quite incompetent for the performance of the vital functions of a warm-blooded animal. All the special endowments, therefore, of Mammalian *life* would necessarily be lost along with the aerial respiration — still it is conceivable, in the nature of things, that some of the peculiarities of the Mammalian *skeleton* might be conjoined with the respiratory organs of the fish.

It is unnecessary farther to multiply instances in illustration of the law of typical form, as those now adduced appear sufficient to show there is some principle involved in the construction of animals beyond the mere adaptation of their organisation to their appropriate spheres of life. Yet we shall certainly never disparage the indications of the latter, if we pursue the study of nature with unprejudiced minds; for even in the common type, and still more obviously in its modifications, characteristic of classes and minor di-

visions, down to species, we may trace clear evidences of the adaptation of the structure to the exigencies of the case.

Authors have shown, for instance, with great detail, how admirably the organisation is fitted to the conditions of life in birds and fishes; while in the bat and whale, which have the habits of these classes, the modifications of the Mammalian structure have so markedly the character of adaptations as to strike even a casual observer. The internal position, again, of the skeleton characterising the whole group of Vertebrata, has an evident relation to the increased sensibility of these animals; for while it provides a special envelope for that system whose great office is sensation, it leaves the exterior of the body unencumbered by hard tissues which would interfere with the reception of impressions from without.

It may be added that one very important modification of the typical conformation — which recurs so regularly in the different classes, as to become itself part of the general plan — seems to be essentially an adaptation of it to a special end. It is matter of observation that in all the classes, as we ascend to the higher species, certain regions lose their uniformly jointed character, by the expansion and partial fusion of the segments. We see this very remarkably in the

cephalo-thorax of crabs and spiders, and in the skull of Vertebrata, for in these cases the modification is so extreme, as completely to disguise their typical formation, which is only traceable by the clue furnished by the corresponding regions in the less highly developed species. This peculiarity has a very obvious relation to the concentration of the nervous and vascular systems, in adaptation to more centralised vitality of the higher species generally.

There is, we believe, great force in the remark of Professor Goodsir, that "morphology and teleology are merely opposite, because, in the present phase of science, necessary anthropomorphic aspects of the same Divine principle, evinced in the laws of organisation."* For it certainly appears a more worthy conception of the plan of organisation adopted by the Divine Architect, to suppose that it is in itself sufficient to meet all contingencies, than to hold that typical development and purposive adaptation are distinct; in the sense that the latter principle provides for what the other is insufficient to effect.

* Op. cit. p. 129.

CHAP. IX.

BEARING ON NATURAL THEOLOGY.

If the cases cited in the preceding pages in illustration of the prevalence and importance of typical forms, have really the weight which is allowed to them by the most eminent naturalists of the day, it certainly appears that, in confining our attention to the adaptation of the structure of animals to their peculiar modes of life, we are far from exhausting the philosophy of organisation: and of course it follows that if, after the general example of writers on Natural Theology, we merely draw inferences of design from such adaptation, we shall do but imperfect justice to the moral lesson which the book of nature spreads before us. For admirable as are these adjustments, and irresistible as is the inference, on the part of every unbiassed mind, of infinite power and wisdom in the Designer, there remains behind another fact, equally marvellous and equally pregnant with hidden truth, namely, the unity of

plan so pervading the construction of each great division of the Animal Kingdom, as to give harmony to specific differences almost innumerable.

Now if the very existence of the creature is an evidence of the power of the Creator,—if the adaptation of its structure to its mode of life tells farther of His wisdom,—if the harmony between its habit and organisation on the one hand, and its capabilities of enjoyment on the other, implies His beneficence, surely this unity of organisation proclaims no less loudly His orderly method of operating: and if so, then is it open for us to trace in the construction of the animal tenants of this globe, the same Divine attribute which, as displayed in the mechanism of the heavens, has from the earliest ages attracted the attention of mankind, and has furnished the greatest intellects of our race with a field for the employment of their powers of research, which, in the very nature of things, can never be exhausted. If, indeed, there be one feature more characteristic than another of the heavenly bodies, it is order, the true music of the spheres. And, however widely we push our investigations, it is still the same, still order, and, what is more, the *same* order throughout the whole. Not only everywhere in our own solar system is there one uniform system, according to which the secondary

planets or satellites describe orbits round their primaries, and these in turn circulate in a precisely similar manner round the central sun; but throughout the farthest bounds of telescopic vision we have reason to believe that the same order prevails. Everywhere suns are seen circulating around other suns, and we can hardly hold back from the conclusion that each carries with it an orderly train of primary and secondary planets.

It matters not, therefore, to which part of the cosmos or material universe we direct our attention, whether we soar into the heights of the *macrocosm*, the great or upper world; or dive into the mysteries of the *microcosm*, that little world of the animal organisation, — in both cases alike are to be seen evidences of design and evidences of order. If we do not find them equally obvious in both, the hindrance is mainly in ourselves. Our doubts as to the existence of sentient beings in other worlds, and our absolute ignorance of their condition at least, interfere of course with our appreciation of marks of design in the disposition of the heavenly bodies; while, from causes already adverted to, our systematic acquaintance with the typical forms of animals is of so recent a date, that it cannot excite surprise that authors have mostly confined themselves to the clear evidences

of design so abundantly furnished by the animal economy.* But this state of matters need no longer continue. As the discoveries of Newton, by showing the law of gravitation to be a principle operating through all space, established a community between the laws of motion on the earth and in the heavens, which the ancients regarded as too diverse to be investigated on the same grounds, so do those of Oken and his successors reveal to us the fact that the principle also of orderly arrangement is common to both.

But it is generally admitted that the teaching of nature should go beyond this, and that the conception of the Creator, directly suggested by the intellectual appreciation of His works, should lead up minds of a proper moral balance to recognise also those higher attributes which form the basis of religious reverence. For somewhat as the still water of the smallest pool on the surface of the earth may reflect the expanse of the heavens, so to the contemplative mind does the natural shadow forth the supernatural, in virtue of that harmony which subsists between the physical and moral operations of the Deity.

* It is but fair to observe that this remark does not apply to some recent works on Nat. Theology, *e. g.* that of M'Cosh and Dickie.

Now, if our conviction of the beneficence of God, as shown forth in animated nature, in this way suggests to us His moral attributes of love and mercy, may it not also be that His orderly method of operating in nature — His manifestation of *physical equity*, as we may call it, shadows out His attributes of *moral equity*, that is, holiness and justice? The one at least seems naturally to suggest the other, as Mr. Ruskin points out in his work on Modern Painters. "Orderly balance and arrangement," he observes, "are essential to the perfect operation of the more earnest and solemn qualities of the beautiful, as being heavenly in their nature, and contrary to the violence and disorganisation of sin: so that the seeking of them and submission to them are characteristic of minds that have been subjected to high moral discipline, and constant in all the great religious painters to the degree of being an offence and a scorn to men of less tuned and tranquil feeling."* He refers here especially to symmetry as an "expression of the Aristotelian ἰσότης (equity), that is to say, of abstract justice;" but symmetry, as we have seen, is only a particular case of the general principle of order.

And here one can hardly forbear remarking how

* Modern Painters, ii. 71. Chapter on Symmetry, or the Type of Divine Justice.

applicable these observations on order, as a ruling principle in high art, are to its existence and influence as an element in the practical development of religious truth. The systematic arrangement so evident in all departments of the material universe, both great and small, find their counterpart in the order of the hierarchy, the adornment of the sanctuary and the ritual of the service, so pointedly enjoined in the ecclesiastical system of the Jews, and certainly not less discernible, though of clearer significance and greater reality, in the Christian Church — the pattern shown in the mount — on which the former was modelled, as a shadow of good things to come.

Yet — strange to say — neither in Oken, by whose penetrating intellect were laid the foundations of the science of typical forms, nor in some of those who since his time have most successfully prosecuted it*, did the principles they unfolded awaken any recognition of the moral attributes of God. Immersed in a dreamy pantheism, they could regard Him only as the animating principle of the universe, or, lower still, simply as a necessary existence inevitably manifesting itself by a continual succession of phenomena, like a great panorama ever unrolling. But the reproach,

* St. Hilaire, Goethe, and some others, principally on the continent.

which has in consequence attached to such investigations, is in reality most unfounded; for, so long as the truth of the Divine personality is firmly grasped, the evidences of unity of organisation, instead of militating against the free agency of the Creator, tend greatly to elevate our conceptions of His power and wisdom. We then see that in His works a greater problem is solved than the mere adaptation of means to ends, for this, without losing any of its completeness, is combined with a certain harmony and uniformity in the means themselves. We see the Almighty Creator, for the manifestation of His glory or other wise purposes, subjecting Himself, as it were, to laws — restricting Himself, so to speak, in the choice of the mechanism of His work, that the power and wisdom which bring it to perfection all the same, may be the more apparent.

And in this, it has been remarked, lies one great distinction between the works of God and those of man; for the latter, as a common rule, keeps the end only in view, and declines to fetter himself by a uniformity of plan, which a finite agent naturally regards as an unnecessary encumbrance. Yet in proportion as individuals are raised by gifts of genius above the common level of their race, so do they seem to be granted a portion of that Divine faculty of combining

completeness of adaptation with unity of operation. We find illustrations of this in all the fine arts, — especially, as it would seem, in poetry, music, and architecture, — and it is, perhaps, in a great degree, to the superhuman impress as it were, which they thus bear, that they owe their power over the minds of men. The true artist, conscious of his power, shackles himself by some conventional law, that his prowess may be enhanced by the artificial difficulties he has had to struggle with, and has overcome.

Thus the great end of poetry is word-painting, the creation of images in the mind by the use of words, as the painter does on canvas by his pencil and brush. To do this perfectly, even with the amplest latitude in the choice of words, is no mean achievement, for eloquence, in its highest form, is a gift possessed by few. But the essential difficulties of poetry are enhanced by its composition in language of some kind of rule or measure, as appears to be the usage of all times and nations. There are differences of language and measure, as there are different types of organisation in animals, but the words employed by the poet are always subjected to some such restraint of rule. In the highest order of poetry, the sentiments and the composition alike bear the impress of a master-mind, for in the success with which he clothes real

poetic conceptions in harmonious diction, consists the merit of the author, and the humanising influence of his writings on those who read them aright.

But this preliminary condition is of absolute necessity, for it is not every mind that can appreciate poetry. There are some who read it merely to scan the verbal composition, and others who see in every work simply a didactic composition. On all such it is needless to say its peculiar excellence is thrown away. Nor is it different with other departments of high art. In all cases, such as confine themselves to its accidental conventionalities, and such as pursue it merely in a utilitarian point of view, alike fail of receiving that benefit which its cultivation in a more liberal spirit would impart.

But if this be the case with human art, which even in its highest development is merely imitative, we cannot surely suppose it different with the creative art of God. Is it not then a fair conclusion, that in the study of nature we should strive to keep in view the whole scope of the operations of its Author, looking as well to the typical forms so universally traceable, as to their adaptation to special ends?

APPENDIX.

APPENDIX.

I.

NOTICE OF SOME CONTROVERTED POINTS.

As the object contemplated in this work was simply to give a fair and intelligible exposition of the typical structure of animals, the author has kept aloof as much as possible from controverted points. It is needless to say there are many such in the extent of ground which has been so rapidly traversed. The chief discussion — as might be expected — has been on the homologies of the vertebrate skeleton; and as it has been stated in Chapter II. that the views of Professor Owen have received the general assent of naturalists, it may be proper to mention here that there are exceptions to this, some writers of note opposing them keenly. Maclise and Goodsir especially have advanced opinions which in many respects are quite incompatible with his.

The exceptions taken to Owen's system appear to be principally the following.

1. — It is alleged that certain bony and cartilaginous elements of the body are rejected from the true internal skeleton, and others retained, according as they are re-

quired or not, to make out the typical vertebræ. Thus the hyoid figures as the hæmal arch of the third cranial vertebra, while the laryngeal and tracheal cartilages — serially related to it — are entirely discarded. In the same way the lacrymal bone and the other orbital plates, the petrous portion of the temporal, &c. are — under the name of sense capsules — also excluded from the vertebral series.

2. — It is contended that in limiting the pieces of a vertebra, as he has done, Professor Owen has given his system a stringency, which does not exist in nature; and it is maintained that the median fins of fishes — which he excludes from the endo-skeleton — may be fairly referred to it, as additional diverging appendages, there being many cases which serve to show, that these are not limited to a single pair in connection with each vertebra.

3. — It is alleged that the parts considered serially homologous (homotypes), as representing the hæmal arch in different regions, present sometimes a fundamental diversity in the relations, as well of their constituent parts to each other, as of the whole arch to the alimentary and vascular axis. Thus in the chest the hæmal arch is intercalated between the extremities of the ribs, which are intimately connected to the transverse processes of the vertebræ; while in the tail — as represented by the chevron bones of some animals — it is made to spring from the under aspect of the bodies of the vertebræ, quite apart from the outstanding transverse processes.

4. — It is objected that the connection of the fore-limb with the occipital segment of the skull in fishes, is no

sufficient ground for referring it to the same vertebral centre in the higher animals, when in actual position it is separated from it by the whole extent of the neck, which in some birds contains more than twenty vertebræ, and in the plesiosaurus seems to have numbered about forty. Such displacement is farther opposed by the fact, that the nerves of the extremity are derived from the portion of the cord corresponding to its actual position.

Lastly, it is maintained that Professor Owen's conclusions are not in harmony with the processes of development observed in the course of embryonic growth.

Though the writer certainly cherishes no presumptuous ambition of being arbiter in such a controversy, he may, without undue temerity, remark that this last objection, if well founded, is of more force than any of the others. For if by homologous parts we mean such as are actually formed in a corresponding way in the construction of the animal fabric, then it is obvious that the surest, and in fact the only convincing demonstration, is that afforded by watching the process of organisation in the course of its progress. The most extensive induction from fully developed forms — however valuable as indicating *probable* correspondences — cannot absolutely prove their reality. It is therefore to be regretted that Professor Owen has not — in addition to his overwhelming mass of evidence from comparative anatomy — farther fortified his position by reference to embryological researches. The very different views maintained by Owen and Maclise on the nature of limbs, may serve to illustrate the impossibility of deciding questions of the kind, with-

out reference to the history of the development of organs. Maclise regards the limbs as a sort of split vertebræ overriding the others; Owen, as diverging appendages of the hæmal arches of vertebræ. Each brings forward illustrations in support of his case from comparative anatomy; but though we may, perhaps without great difficulty, decide on which side lies the balance of probability, the nature of the evidence adduced is not such as to carry us beyond the region of probabilities. The same remark applies even more strongly to another *questio vexata* — the number of vertebræ entering into the composition of the skull; — the diversity of views as to which has tended not a little to throw discredit on the whole doctrine of homology. Thus while Oken, the founder of the system, and Spix, admit only three; Bojanus, Blainville, and Owen make the number four; Goethe, Carus, and Maclise reckon six; and St. Hilaire, Grant, and Goodsir, seven. Again, while Maclise and Goodsir think the number may vary in different animals, the others seem to consider it as fixed. The value of embryological observations in settling such disputed points is fully admitted by Professors Huxley and Allman, who are at variance in regard to some points in the homologies of the lower Mollusca. They only regret not being at present sufficiently in possession of data from this source to determine the question.

Owen's principal opponent on embryological grounds, is Professor Goodsir, and it cannot be denied that he makes out a strong case — especially in favour of the fore-limb of the higher Vertebrata being independent of the skull from the very first. He is inclined to think that a limb does

not necessarily derive its elements from a single vertebral segment — "about fifty segments of the trunk appear to contribute towards the structure of the great pectoral fin in the ray." Even the human arm he seems to regard as derived from five segments — the original number being represented by the extreme bones of the hand; those of the proximal divisions, up to the shoulder, being progressively reduced by abortion of some of their primitive elements, so as to leave in the wrist but four bones in each row, in the fore-arm but two, and in the arm proper but one. The shoulder bones he does not regard, with Owen, as the hæmal arch of a vertebra, but as of the same nature with those of the extremity itself — simply the proximal elements of a series of bones, which altogether make up a diverging appendage. The first link in the chain is represented by the scapula, the next by the clavicle and coracoid jointly; then follow the humerus and other bones of the extremity in their order. Of course a similar view is taken of the pelvic extremity.

Professor Owen's explanation of the multiplication of the ray-bones in the fins of fishes, on the principle of "vegetative repetition," he regards as unphilosophical; the marked influence of the constant number of five — as fully shown by Owen himself, in the digits of the higher vertebræ, — being inconsistent with the notion that a process of indefinite subdivision of the same parts may go on in fishes. Yet that there really exists in nature something like what Owen probably means by "vegetative repetition," *i. e.* the budding off from one piece or segment of a number of others, in succession, similar to itself — seems to be shown by the formation in this way

of the segmented body of the tapeworm, of the strobilæ of certain polyps, and of additional joints in some Annelida. Is it not, too, by such a "vegetative repetition" that the origin of double monsters is most satisfactorily explained; each half of the cleft portion of an embryo reproducing the separated parts? One is even inclined to surmise that a normal process of the same kind may be concerned in the extreme multiplication of the vertebræ in the spines of vermiform fishes, and the long necks of some birds. At all events these seem to be favourable structures for the observation of such germination or "vegetative repetition," if it really occurs in the case of Vertebrata.

It will be seen that the controverted points do not affect the general statements in this work concerning the vertebrate type of organisation; though obviously some of the illustrations employed — as that of the chevron bones — would not be allowed by Professor Goodsir to be in point. On the whole, the questions in dispute refer rather to details of ossification than to the general disposition of the bony shell of the body and its contained viscera, which have been the subjects principally under our consideration.

Another point which has given rise to discussion concerns the relations subsisting between the vertebrated and articulated types. It was indeed by the perusal of a controversial passage in Owen's "Comparative Anatomy of Fishes" (p. 51) that the author was first led to adopt the views on this subject which he has now taught for several years, and of which he has given an abstract at the close of Chap. IV.

In the passage referred to, Professor Owen objects to the notion of Geoffroy St. Hilaire, that "it needed but to reverse the position of the Crustacean — to turn what had wrongly been deemed the belly, upwards — in order to demonstrate the unity of organisation between the Articulate and Vertebrate animal;" — that "the position of the brain is thereby reversed, and the alimentary canal still intervenes between the aortic trunk and the neural canal." The latter objection was met by reflecting that the dorsal vessel of the articulate animal corresponds, not to the descending aorta, but to the heart of Vertebrata taken in connection with the inferior cava and the ascending aorta. These together make up the great vascular axis, which is represented in the fish by the venous sinus, the single heart and the great branchial trunks, and which in the early embryonic condition of all Vertebrata has still more the character of a cardiac-arterial tube, such as forms the vascular axis lying along the back of all classes of Articulata. But the other difficulty — depending on the apparently dorsal position of the "brain" in the majority of this class — was felt by the author a considerable embarrassment, till he was informed by one of his pupils (in November, 1856) of Professor Goodsir's doctrine, that the typical position of the cephalic ganglion is really in front of the mouth, forming one neural axis with the chain of ventral ganglia. It was not till his own remarks in the present work were written, that he had the pleasure of finding, by the perusal of Mr. Goodsir's paper referred to below, their general accordance with the views of that distinguished anatomist.

II.

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A LIST is here subjoined of some of the more accessible publications in which the subjects of our inquiry are treated at greater length, for the direction of any who may be led by the sketch now offered to them, to pursue the study of homological science in a more systematic way.

The works are arranged in the order in which their several subjects have now been considered. Few references are made to periodicals or foreign works.

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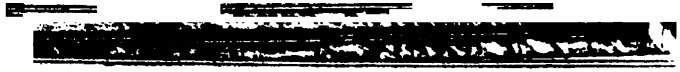
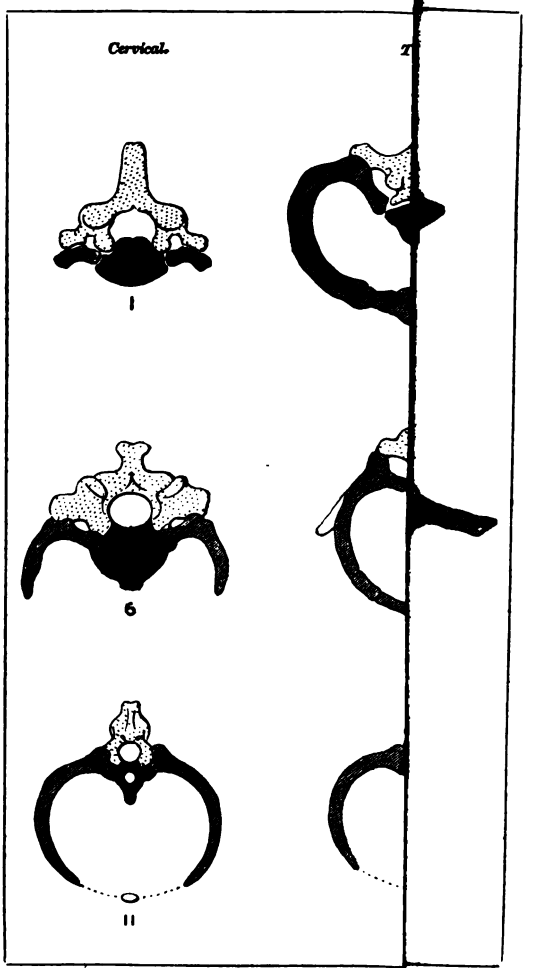
EXPLANATION OF THE PLATES.





Cervical:—

1. Man.
6. Ostrich.
11. Serpent.

Tho
1
7
1

Plate I.

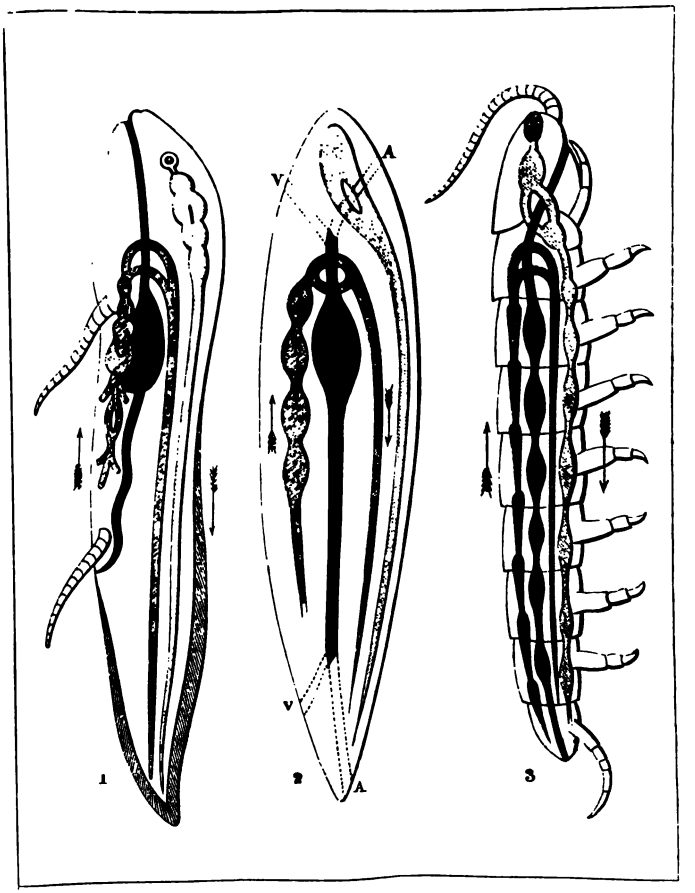
Plate I. represents the vertebral elements of the several regions of the trunk of the body in various animals.

The figures of the upper row show the vertebral elements as they occur in the cervical, thoracic, lumbar, pelvic, and caudal regions of the human body; while in the two lower rows are represented, under each region, the development characteristic of some of the lower animals, but without regard to their natural proportions of size.

The body or centre, which is the most constant element, is shaded dark in all the figures, while the lower or hæmal arch — often imperfect — is shaded light, and the upper or neural arch — which is always complete when present — is marked by a dotted shading. The diverging appendages, as in figures 4, 7, 9, 13, and 14, are drawn simply in outline.

Such of the figures as are copies are mostly taken from Professor Owen's works, one or two being from Maclise's article "Skeleton," in the Cyclopædia of Anatomy and Physiology.

Plate II.



1. LONGITUDINAL SECTION OF A VERTEBRATED ANIMAL.
2. COMMON PLAN OF A SEGMENTED ANIMAL.
3. LONGITUDINAL SECTION OF AN ARTICULATED ANIMAL.

PLATE II.

PLATE II. represents, in a diagrammatic form, the relations of the visceral organs in a vertebrated, as compared with an articulated animal.

The central figure shows, in a supposed vertical section along the axis, the plan of construction, in so far as it is common to both forms; the skeleton and the limbs being omitted.

The systems represented are —

The nervous axis, in dotted shading;

The heart, and the returning vessel or aorta, shaded light, with arrows marking the direction of the circulation;

The alimentary canal, shaded dark.

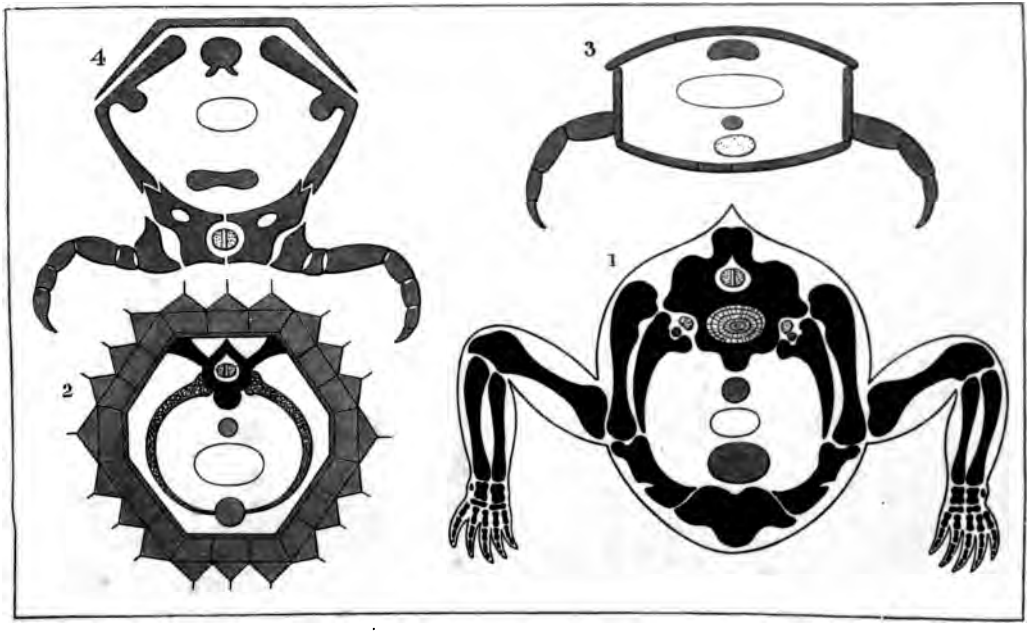
The last system can be shown only in part in the common plan, as its orifices open on opposite aspects in the two forms. The dotted lines V V show the direction of the terminal portions of the alimentary canal in Vertebrata; and A A the same in Articulata.

If, now, this diagram of the common plan be laid on its hæmal side, or that occupied by the heart, if the orifices of the alimentary canal be represented on this side, and the proper number of limbs be also appended to it, we have then an illustration of the plan of a Vertebrated animal or *Hæmapod*, such as is given in the figure on the left-hand side of the plate. The general outline selected is that of the Lepidosiren, the internal skeleton being left out.

If, on the other hand, the common diagram be laid on its neural side, or that occupied by the nervous axis, if

the alimentary and intestinal orifices be transferred to the same side, and a series of limbs be also appended to it, then we have an illustration of the relations of parts prevailing in an Articulated animal or *Neurapod*, as is shown in the figure on the right-hand side of the plate, made up of a few segments of the Centipede.

Plate III.



TRANSVERSE SECTIONS OF VERTEBRATA AND ARTICULATA.

1. Crocodile. 2. Ostracion. 3. Centipede. 4. Crayfish.

Plate III.

Plate III. represents the relations of the same systems as the foregoing, along with those of the skeleton, as shown by vertical sections, transverse to the axis, in Vertebrated and Articulated animals.

In all the figures of this plate, the section of the alimentary canal is represented by a simple outline, that of the nervous cord by a dotted shading, and those of the blood-cavities by a light-lined shading; while the skeletons both external and internal are drawn dark, the latter most so.

In all the sections the alimentary canal will be seen to occupy the middle place. In those of Articulated animals, in the upper part of the plate, the nervous cord is shown below this canal on the ventral aspect, and the heart or great blood-cavity above it on the dorsal aspect; the returning vessel lying on the ventral aspect between the cord and the alimentary canal. In the majority of Articulata there are two returning blood-canals or sinuses on the ventral aspect; and these, in some Crustacea, are united at intervals by transverse communications. In the Cray-fish (*fig.* 4) the section is supposed to pass through one of these connecting branches.

In the sections of Vertebrata, again, in the lower part of the plate, the heart or great blood-cavity is placed below the alimentary canal on the ventral aspect, while the returning vessel or aorta and the nervous cord lie above it on the dorsal aspect; though they are separated from each other by the central column of the spine, and occupy different cavities in the skeleton; the upper or

neural canal being filled with the nervous cord alone, while both the vascular trunks are associated with the intestine in the interior of the lower or hæmal canal.

In the Invertebrata, from the absence of an internal skeleton, all the viscera occupy the same general cavity, as is shown in the section of the Centipede (*fig.* 3); and though in the higher Crustacea a sort of imperfect neural canal is formed in the thorax by projections (or *apodemata*) reaching inwards from the hardened integument or external skeleton, as is represented in the section of the Cray-fish (*fig.* 4), yet the separation is never complete, from the want of the fundamental element of a true internal skeleton, the central column of the spine.

In the majority of Vertebrata, again, as in the Crocodile (*fig.* 1), it is the internal skeleton only that is well developed; the external being rudimentary. In a few species, however, as in the Ostracion or Trunk-fish (*fig.* 2), the latter is in advance of the other, many elements of which remain in the rudimentary condition of membrane or cartilage.

The originals of figures 2 and 4 in this plate will be found in Professor Owen's Comparative Anatomy of Fishes.

For a fuller explanation of this and the foregoing plate, the reader is referred to the general statement of the characteristics of Vertebrata and Articulata in the body of the work.

THE END.

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